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LOCALIZER TRAVELING WAVE ANTENNA DEVELOPMENT.(U)
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LOCALIZER TRAVELING WAVE ANTENNA DEVELOPMENT

CARL G. PETERSON

MAY 1976

FINAL REPORT

U.S. DEPARTMENT OF TRANSPORTATION

FEDERAL AVIATION ADMINISTRATION

Systems Research & Development Service

Washington, D.C. 20590

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16. Abstract

Federal Aviation Administration Systems and Research and Development efforts through a contract with Andrew Alford Consulting Engineers have resulted in the development of a set of ILS localizer antenna arrays of the traveling wave type. These arrays including integral monitors have been shown capable of overcoming the major shortcomings associated with earlier antennas. The results of this effort are summarized. Distinguishing performance characteristics are pointed out for each of the so-called Type O, 1A, 1B and II antenna arrays.

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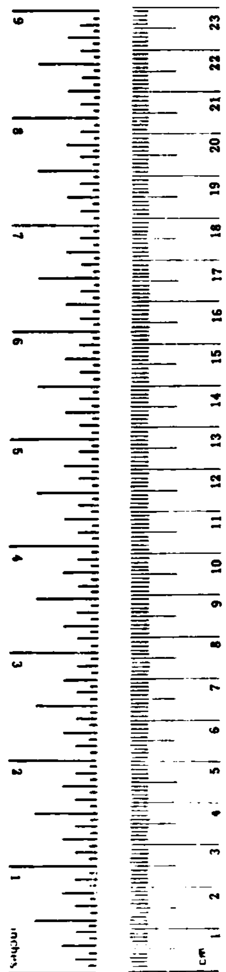
METRIC CONVERSION FACTORS

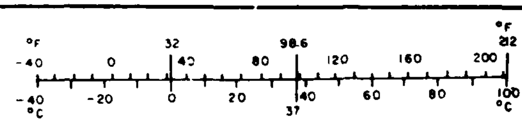
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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1.0 INTRODUCTION

The VHF localizer has existed in general operational use for well over three decades, as part of the ILS, to provide horizontal guidance for aircraft approaches to airports. The localizer generates a more or less directional tone modulated radiation pattern centered about a runway centerline extended to produce proportional left or right instrument deviation indications in an airborne receiver depending on the aircraft location within the localizer course sector and full scale deviating indication (called clearance) elsewhere within the localizer signal coverage. All localizers in general conform to the International Standards and Recommended Practices of ICAO Annex 10.

Since its original inception many improvements have been introduced to the system along the lines of electronics and antenna developments. The design and performance characteristics of the radiating antenna array is of special importance due to the critical necessity for accurate guidance with decreased visibility and approach minimums. A potential problem is that at many airports, the radiated signal could be adversely affected due to reflections from buildings, taxiing aircraft, etc., thus limiting the accuracy and use of the localizer during low visibility.

This report presents the results of a major development effort for antenna arrays which overcome weaknesses of existing systems and are suitable for practically all types of airport sites.

2.0 BACKGROUND

For a background of the development effort, it would be well to briefly summarize some of the difficulties associated with the existing localizer antenna arrays in operational use by FAA during the Fifties and Sixties, namely (1) the 39-foot aperture single frequency eight-loop array, (2) the 117-foot aperture two frequency waveguide (with its eight-loop array for clearance and backcourse), and (3) the 105-foot, single frequency, 15-element V-Ring array.

All of these arrays were developed at a time when FAA required both a front and a back course and full scale clearances at all azimuths between the front and back course sector width limits. Due to increasingly difficult siting conditions created by normal airport expansion, these arrays were hard pressed to provide Category II (and in many cases even Category I) performance. The siting problem was further aggravated by the introduction of larger and higher performance jet aircraft which required better localizer beams for operation with their couplers. None of the existing arrays were designed to take advantage of a newly implemented policy which deleted the requirements for a back course and for clearances beyond ±35° of the front course. Each used individual radiating elements with little or no directivity. They all suffered from now absolete and overly sensitive monitor pick-up arrangements resulting in instabilities and susceptibility to weather. The design did not take into account overflight interference and means of minimizing it. Specific shortcomings in each array had been noted as follows:

Eight-loop array. Due to its small aperture, its course quality is not good for Category II or even Category I in many cases. Its clearances are generally marginal. The array had to be "tailored" to each site with special screening in many cases resulting in high initial installation and flight inspection costs.

Wave guide system. Initial production costs for this "brute force" type of an array as well as the costs for the "tailored" installation and flight inspection are very high. In addition, the waveguide required a separate eight-loop array for clearances and the back course.

V-Ring array. The single frequency V-ring array represented a compromise design with a complex antenna element. In spite of its complexity, it would not meet Category II requirements for course quality and clearance at many sites. It has been susceptible to severe monitor problems and suffers from the effects of mutual inductance coupling. It requires precise on-site tuning for each frequency.

Contract DOT-FA70WA-2253 was awarded on October 27, 1969, to Andrew Alford Consulting Engineers, Winchester, Massachusetts, for a theoretical design study and the development, fabrication and test of three new state-of-the-art types of localizer antenna arrays which would meet the latest operational requirements and overcome the deficiencies described above.

Some of the major provisons of the contract requirements included performance in accordance with the ICAO requirements, accommodation of the antenna arrays to any typical type of siting environment, more directive antenna elements with built-in individual monitor probes, reduced antenna element to element mutual coupling, no antenna adjustments over the frequency band, add-on capability to a given array to achieve improved performance, and maximum time delay of one second as allowance for interference caused by overflying aircraft. For the more difficult sites, the two-frequency concept was re-introduced.

This development has essentially met or exceeded all the original engineering requirements. The result has been a common traveling wave antenna element and five basic antenna arrays or combinations of arrays assembled from the common element, namely (1) the type C6-1, a six element clearance array (2) the type 0, an eight-element single frequency array (3) type 1A, a 14-element single frequency array (4) type 1B consisting of a 14-element directional array used with the six-element separate frequency type C6-1 clearance array and (5) type II, consisting of a 22-element directional array and used with the eight-element separate frequency type 0 clearance array.

The most economical selection of an array obviously requires consideration of the siting conditions as well as the performance Category (I, II or III) that is to be established for the localizer for a given site. A special study was performed by the Contractor to establish selection guidelines. This effort resulted in Report No. FAA-RD-75-64 "A Guide for the Selection of Antenna Characteristics for Single Frequency and Two Frequency Localizers in the Presence of Reflecting Structures." This report is considered an invaluable aid to the installation engineer.

3.0 DETAILED TECHNICAL DESCRIPTION

3.1 Antenna element. All five antenna arrays developed by Andrew Alford Consulting Engineers are made up from the same basic element, namely the traveling wave loop antenna, also called the 0 element or, by the Alford designation, Type 4770 element. See Figures 1 through 3.

The traveling wave loop antenna element consists of 15 radiating and partially overlapping rings, spaced 12.75 inches apart at the point of attachment and slanted across an open common balanced transmission line consisting of two bars terminated by a resistive load. The sending and receivingends of the balanced transmission line are provided with baluns for conversion to unbalanced input and output terminations respectively. The output balun is terminated in a 50 ohm impedance. The spacing between the rings was chosen to produce a very low value of radiation along the back course when the element is properly terminated. The directional characteristics of radiation pattern can be seen from Figures 5, 6 and 7. It can be seen from these drawings that the radiation from the antenna is essentially unidirectional and that it consists of a single major lobe. The mutual inductance characteristics between adjacent antenna elements is excellent and is at least -34db at the minimum spacings used between elements in an array. The element which is 18 feet long (about 2λ) is typically mounted at a height of not over 2/3 λ (approximately 72 inches) above ground and presents a relatively low profile andyet produces a low angle vertically directive radiation pattern.

Other electrical characteristics include the following. The overall element input impedance is 50 ohms. The element will handle a power input of up to 75 watts. The transmitting frequency capability is from 108 to 112 MHz without any antenna adjustments. The input VSWR is less than 1.1:1 over this band. The polarization is horizontal with the vertical component at least -26 db from the horizontal. The front to back ratio is 26 db+. The performance of the antenna element is not seriously degraded from icing; however, to insure no degradation of the performance and for protection of the elements, these are usually enclosed in a radome as shown in Figure 1. To monitor the power level radiated from an element, the power existing at the output termination of the element may be sampled. Samplings from each element in an entire antenna array are combined to provide an analog monitor for the entire array, as will be shown later under the discussion of monitoring of the array.

3.2 Antenna Arrays. As mentioned already, there are several antenna arrays. These are all made up from the same basic element. The arrays have been designed in such a way that regardless of the number of elements, the spacing of the two center elements are identical (i.e., .6λ between each other or each .3λ from the middle of the array, at 110 MHz) and the spacing between all additional elements is also identical,

namely .75λ at 110 MHz. In all cases an even number of elements is utilized which helps the mutual coupling problem. No spacing adjustment is required for a frequency change within the band. However, each type of array requires its own power distribution scheme. Figures 10 and 11 show two types of input power distribution networks.

Five distinct arrays have been developed:

(1) 6 elements	32-foot aperture, provides clearance radiation on a separate frequency for the 1B array (Type C6-1)
(2) 8 elements	45-foot aperture, provides clearance radiation on a separate frequency for the Type II array, or may be used alone as a self clearing array (Type O)
(3) 14 elements	83-foot aperture used as a self clearing single frequency localizer antenna (Type 1A)
(4) 14 elements	83-foot aperture, directional array (Type 1B) on one frequency, used together with Type C6-1 for clearance
(5) 22 elements	140-foot aperture directional array (Type II) on frequency used together with Type O for clearance

Table I displays antenna element spacings for each array. Tables II and III list the nominal current amplitudes and phase of the currents applied to each antenna element of each array.

TABLE I

Antenna Spacings in Wavelengths from Center of Array

Element Number	C6-1	0	1A	1B	II
1L and 1R	.3	.3	.3	.3	.3
2L and 2R	1.05	1.05	1.05	1.05	1.05
3L and 3R	1.8	1.8	1.8	1.8	1.8
4L and 4R	N/A	2.55	2.55	2.55	2.55
5L and 5R		N/A	3.3	3.3	3.3
6L and 6R			4.05	4.05	4.05
7L and 7R			4.8	4.8	4.8
8L and 8R			N/A	N/A	5.55
9L and 9R					6.3
10L and 10R					7.05
11L and 11R					7.8

Note 1: The "L" and "R" suffixes to the element numbers designate the left side and right side of the arrays as seen by an aircraft on approach or an observer standing in front of or facing the array.

Note 2: The physical locations of the element pairs with respect to centerline remains constant throughout the localizer frequency band. The electrical distances will accordingly vary as the operating frequency differs from 110 MHz.

TABLE II

Antenna Carrier Current Relative Level and Phase

Element Number	C6-1	0	1A	1B	II
1L and 1R	1.000	1.000	1.000	.893	1.000
2L and 2R	0	.363	.394	1.000	.964
3L and 3R	.200	.143	.394	.714	.892
4L and 4R	N/A	.055/180°*	.212	.491	.791
5L and 5R		N/A	.212	.263	.669
6L and 6R			.060	.160	.538
7L and 7R			.060	.160	.411
8L and 8R			N/A	N/A	.297
9L and 9R					.206
10L and 10R					.140
11L and 11R					.101

*Everywhere except here, relative phase is 0°.

Note: The "L" and "R" suffixes to the element numbers designate the left side and right side of the arrays as seen by an aircraft on approach or an observer standing in front of and facing the array.

TABLE III

Antenna Sideband Current Distribution Relative Level and Phase

Element Number	C6-1	0	1A	1B	II
1L and 1R	.900/0°/180°*	1.000	1.000	.222	.057
2L and 2R	.300	.890	.759	.667	.169
3L and 3R	.0125	.700	.414	1.000	.277
4L and 4R	N/A	.416	.586	1.000	.326
5L and 5R		N/A	.276	.889	.387
6L and 6R			.379	.555	.369
7L and 7R			.138	.367	.352
8L and 8R			N/A		.281
9L and 9R					.233
10L and 10R					.135
11L and 11R					.130

*This phase relationship applies to all values in the table.

3.3 Antenna Performance. The minimum performance array, Type 0 as described herein is self-clearing (i.e., a single frequency rf carrier provides a course as well as full clearances). It is intended for use at locations relatively free from reflection interference sources in the 180° front course azimuth sector of the array. In comparison, the 14-element, type 1A array, also self clearing, which directs a greater proportion of the radiated energy along the runway centerline, may be used at locations having a moderate extent of interfering sources in front of the array. The radiation patterns of these two arrays are shown in Figures 8 and 9, respectively.

A graphic comparison among several arrays is presented in Figure 12 which shows the relative distribution of sideband radiation versus azimuth of several arrays. Note in particular the relative amplitudes of the 8-loop array, the 15-element V-Ring Array, the Type 0 and Type 1A array. In general, the greater the relative level of off-course sector radiation the greater the potential is for a reflecting source at these azimuths to cause a reflected signal to combine with and deteriorate the signal elsewhere within the coverage including the course where beambends may be caused. The improvement made possible by the introduction of the traveling wave antenna arrays, when compared to the previously existing arrays, is obvious.

Figures 15-20 are presented to show the radiation patterns of the Type 0 array as frequency and course widths are changed from one operating limit to the other. The Type 1B (which includes the 14-element directional arrays plus the C6-1 clearance array) will provide Category II localizer course quality even at difficult sites and may also be used for Category III ILS application. A typical radiation and ddm pattern is shown in Figure 21.

The radiation pattern for the Type II array as shown in Figures 22 and 23 shows the exceptional directional course characteristics of this array. The Type II array has been proposed as suitable for application at difficult Category III sites.

To date all the types have been installed and tested, and all, except the Type II array have been put into operational commissioned use.

Each of the five separate arrays described (C6-1, 0, 1A, 1B and II) is driven by two separate input signals consisting of a modulated carrier (CS) and a carrier suppressed double sideband signal (SO), through an input distribution network. This network which is different for each array, distributes each signal to the elements in the relative nominal current ratios and phase as indicated in Tables II and III. The antenna input distribution networks are illustrated in Figures 10 and 11 for the Type 0 and Type 1A arrays, respectively. The relative ratio between CS and SO determines the course width for a single array (compare, for example, Figures 15 and 16). No backcourse is generated. When two

separate carriers are employed (Type 1B and II), the course radiation carrier predominates within the course sector and the separate clearance rf frequency carrier at azimuths beyond the capture points where the two are equal in amplitude. Any reflections of the clearance energy into the course sector is discriminated against by the so-called "capture effect" in the receiver, i.e., the non-proportional discrimination to the weaker rf signal by the predominant course rf signal. The relative power ratio of the signals to each array is adjusted to provide an overall acceptable course width and clearance. On the courseline, the clearance carrier is nominally 10 dB below the course carrier. Figures 21 and 23 show the resultant ddm distribution from the dual frequency 1B and II arrays.

TABLE IV summarizes some additional comparison characteristics among the arrays.

3.4 Monitoring. All the antenna arrays described are provided with integral monitor pick-up systems which will supply localizer on-course and off-course status signals for conventional, i.e., typical FAA in-use monitors. The shortcomings of the monitor systems previously described such as environmental effects, overflight interference, and time delays have been eliminated by the integral monitor system. The integral monitor system effectively samples the energy radiated from each element of the antenna array and recombines these signals to accurately represent far field course, and course deviation sensitivity or clearance behavior.

The monitor combining networks shown in Figures 10 and 11 are typical for all the arrays, except, of course, for the number of antenna elements involved. In the system shown in Figure 10, the signals are sensed by eight dual couplers representing the terminal loads connected to the outputs of each of the eight-antenna elements. The coupling loss is about 14 db. A set of one signal from each coupler is taken and fed through cable lengths chosen to be of equal electrical length between each coupler and the inputs to a 9-port resistive star combiner, the output port of which represents the combined rf signal which is fed to an on-course detector. A set of a second signal from each of the eight couplers is taken and fed to the inputs of a second 9-port resistive star combiner, the output port of which produces the combined rf signal which is fed to the off-course detector. However, in the case of the signals fed to the star combiner for the off-course detector, their electrical paths are not equal. In this case, instead, for example starting with the cable from the extreme left coupler and going to the right, each successive cable is increased in length by an electrical length made equal to d Sin Θ_o where d is the distance in electrical degrees at 110 MHz between two adjacent antenna elements and Θ_o is the off-course angle at which the signal is to be monitored, typically 2° from the course center line. The value of Θ remains constant in a given system after it has been chosen. The combined off-course signal that is produced is essentially the same signal that wuld be picked up by the off-course dipole in the field at an angle Θ_o provided that the dipole were placed far enough from the array to be effectively located in the "far field," i.e., beyond $2D^2/\lambda$ where D is

TABLE IV

Summary of Characteristics of Traveling Wave Antenna Arrays

Type	0	1A	1B	II
Aperture	45'	83'	83'	140'
Separate clearance aperture	N/A	N/A	32'	45'
Total No elements	8	14	20	30
On course aberrations due to reflection ±15° to 35° compared to V-Ring array	2X	1X	.2-.1X	.1X
On course aberrations due to reflections beyond ±35°	Unlikely problem	nil	nil	nil
Carrier beam width	20°	9°	7° (dir.)	4° (dir.)
SB Lobe widths	10°	4.5°	4.5 (dir.)	3° (dir.)
SB Lobe peaks	±8°	±5°	±4.5°	±3°
Typical power input Dir. antenna (watts)	5	5	9	6
Power input clearance antenna	N/A	N/A	3	3
Radiation beyond desired coverage sector as compared to maximum	10% @ ±40° little beyond ±50°	10% @ ±40° little beyond ±50°	(dir)5% @ ±11° nil beyond ±8°	(dir) 5% @ ±[illegible] nil beyond ±8°

the width of the array and λ is the wavelength. For a 100-foot array, this is approximately 2,200 feet from the array. The arrangement adopted for the off-course signal combiner approximates the ideal arrangement in this repect and provides a signal similar to one that would be picked up in the far field.

3.5 Field tests and implementation. At an early stage of the development effort two significant field tests were conducted, one at Tulsa, Oklahoma and the other at Boeing Field International.

The following is an excerpt from Contractor Progress Report No. 22 which covered field testing at the Tulsa International Airport in August 1971.

"The V-ring generated localizer course serving runway 35R at Tulsa, Oklahoma is very rough because of the erection of a large hangar for Boeing 747 Airplanes. Depending upon whether the doors are open or closed, the course bends vary between 45 and 60 microamperes.

The recently completed tests at Tulsa were undertaken to determine whether a CAT II localier course could be obtained with a two-frequency system consisting of a fourteen element traveling wave course array (FAA 1B) together with an eight element (FAA Type 0) array as a clearance array, or a six element C6-1 Clearance Array.

Several combinations were tried. Every combination after some adjustment of input powers, resulted in a CAT III performance. The arrangement recommended as the result of the test consists of the fourteen element course array (FAA Type 1B) placed at 580' from the runway and a six element clearance array C6-1 placed 780' from the runway."

The field tests at Boeing Field International were conducted a year later and included testing of all the newly developed antenna arrays. The Boeing field was considered a difficult site for localizer installations as the existing localizer waveguide installation only yielded Category I course quality performance. It was found that the Type 2 (actually the same as Type II as described in this report) would provide Category III course quality. The Boeing tests served to demonstrate the relative performance capability of all the traveling wave antennas and the existing waveguide and eight loop arrays. A major excerpt of the Contractor's progress report for this phase of his development effort has been included as an Appendix to this report.

To date some 130 each type 1B systems built by Texas Instruments Inc. for the USAF and FAA have been or are scheduled for installation.

More recent development efforts by Andrew Alford Consulting Engineers under a subsequent contract have resulted in a single combined both course and clearance array with performance comparable to type 1B. Additionally, special monitor arrangements including antenna misalignment detectors and rf cable deterioration detectors have also been developed and field tested under this contract. A separate report is anticipated on these developments.

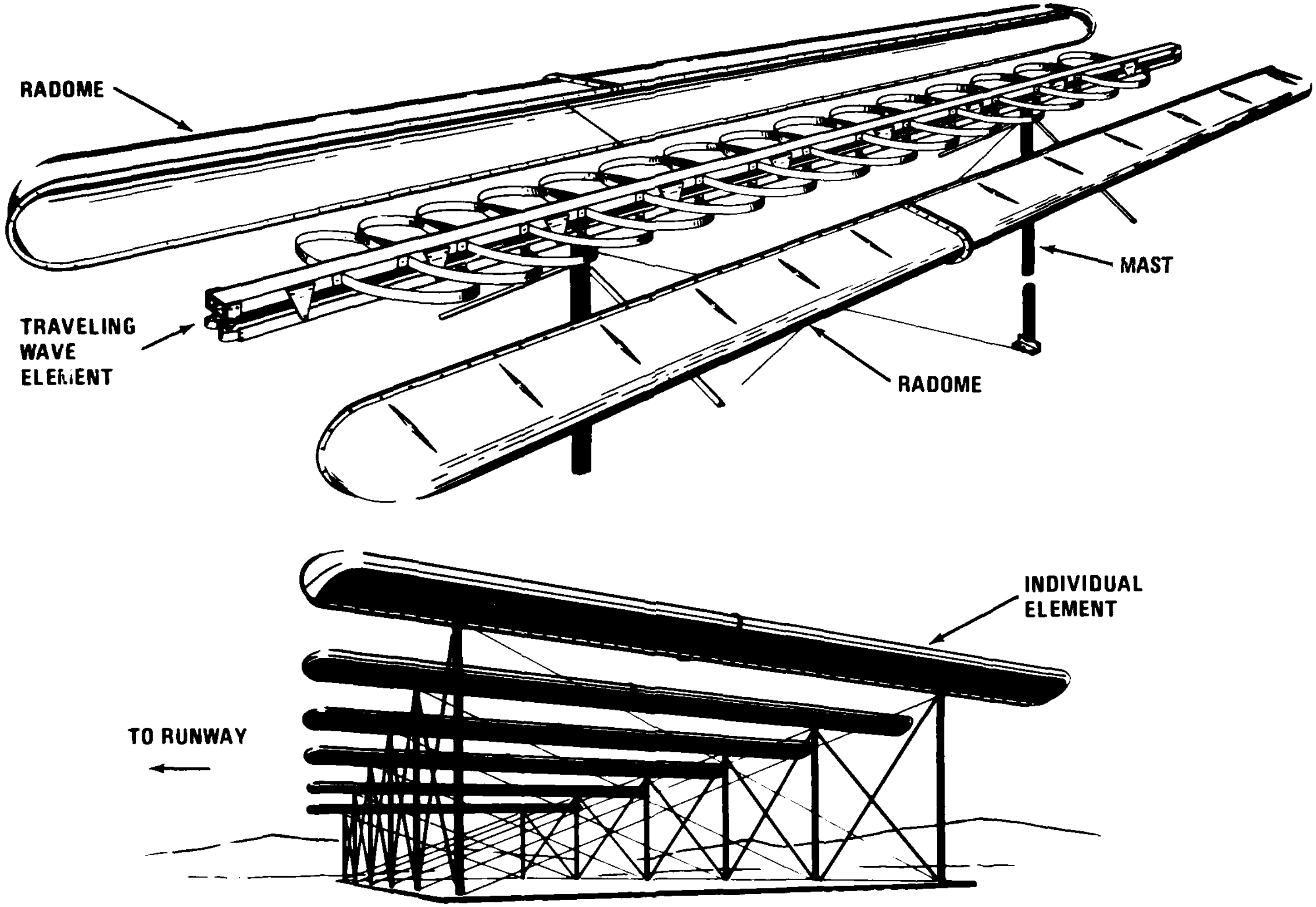


FIGURE 1
TYPICAL ELEMENT AND ARRAY

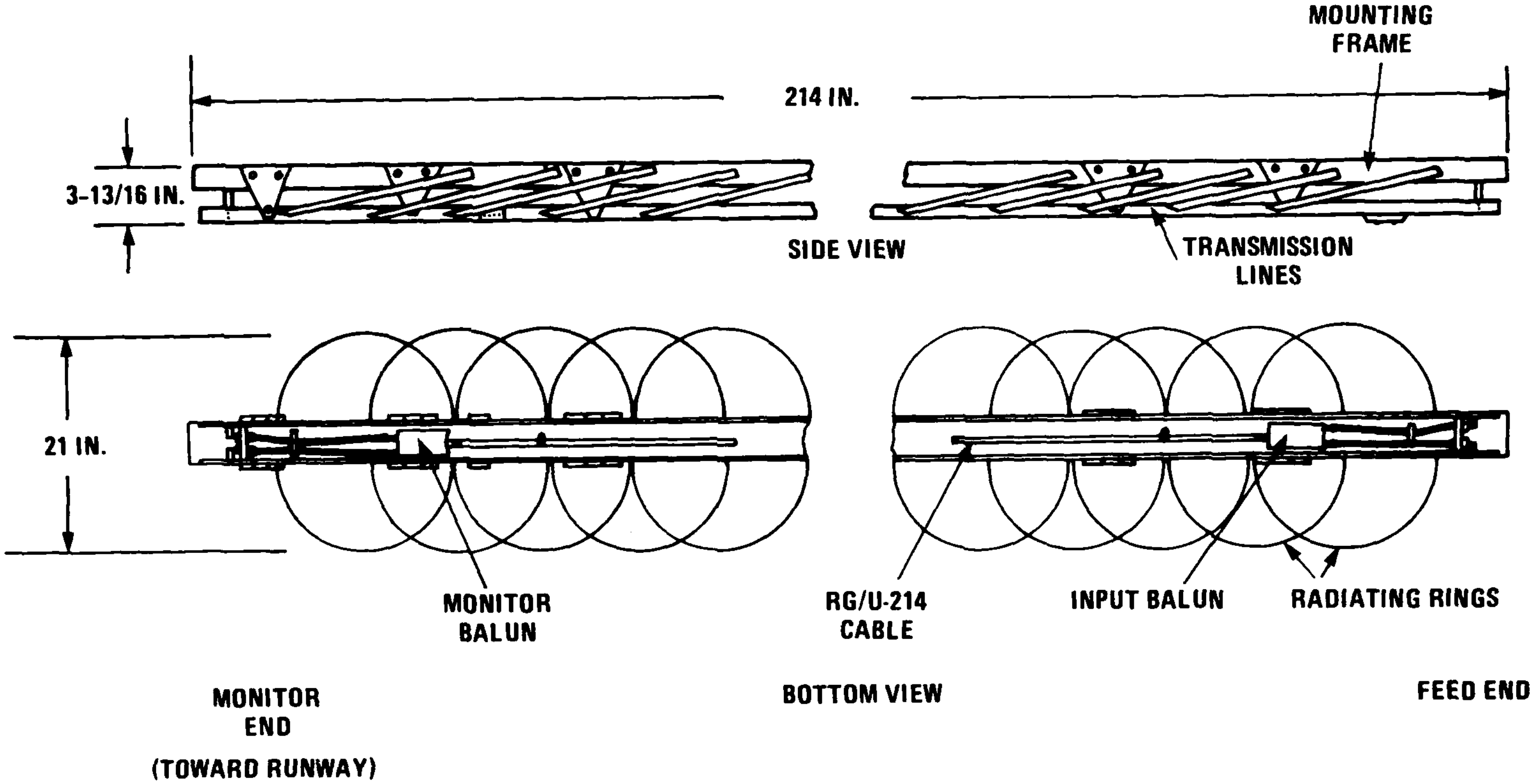


FIGURE 2
TYPICAL
SINGLE TRAVELING WAVE ELEMENT

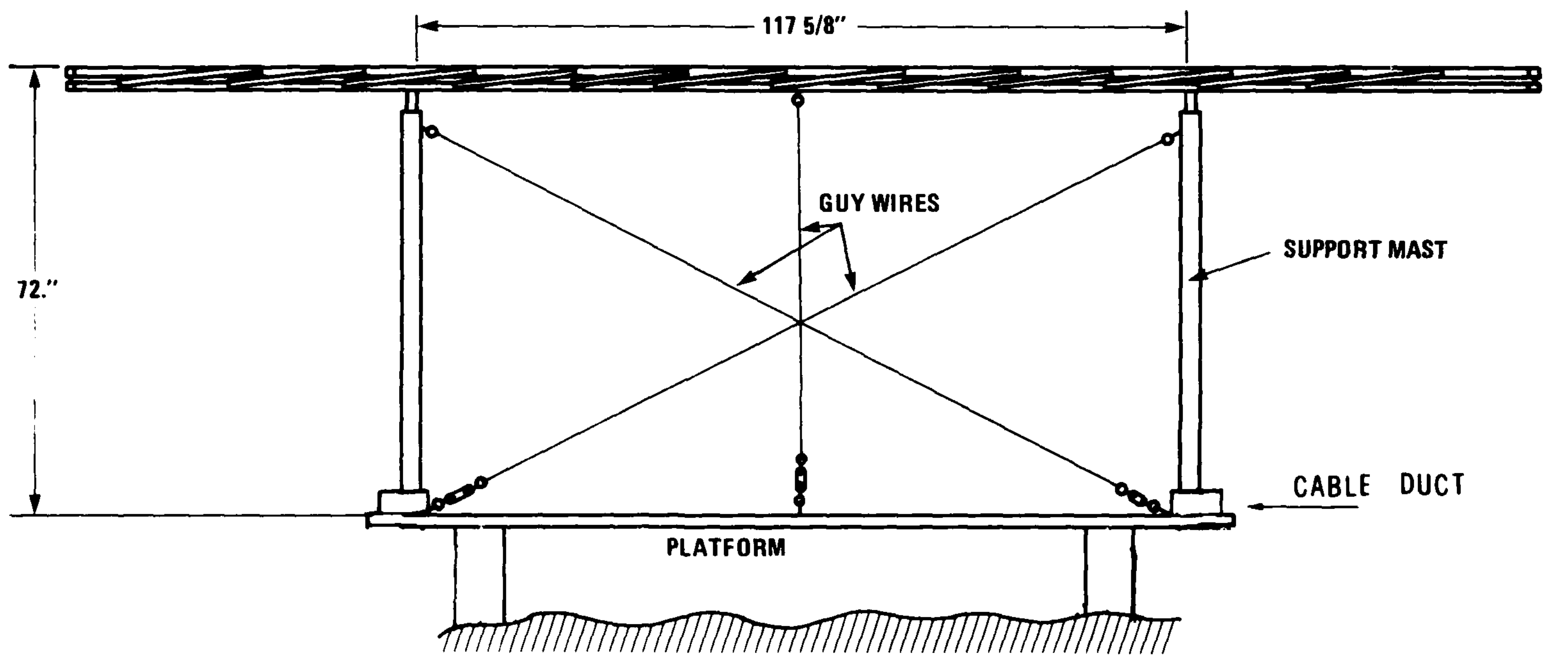


FIGURE 3

TYPICAL MOUNTING DETAILS
OF TRAVELING WAVE ELEMENT

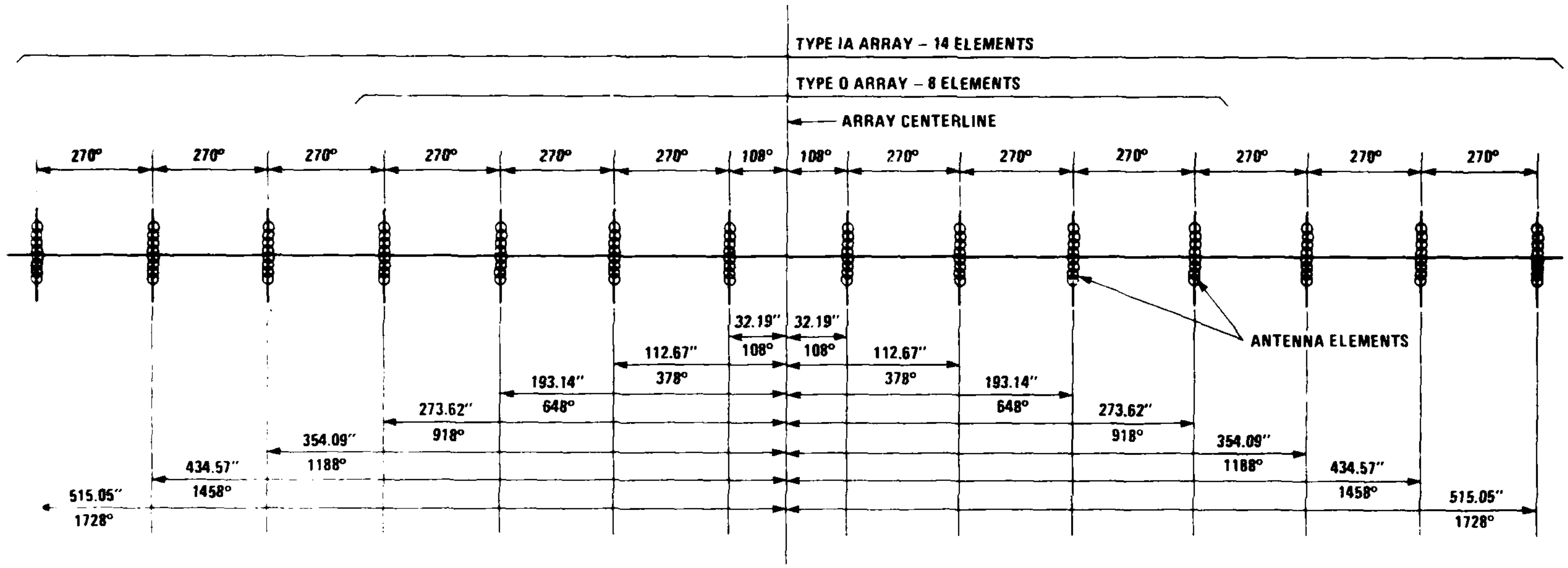


FIGURE 4
ARRAY ELEMENT SPACING

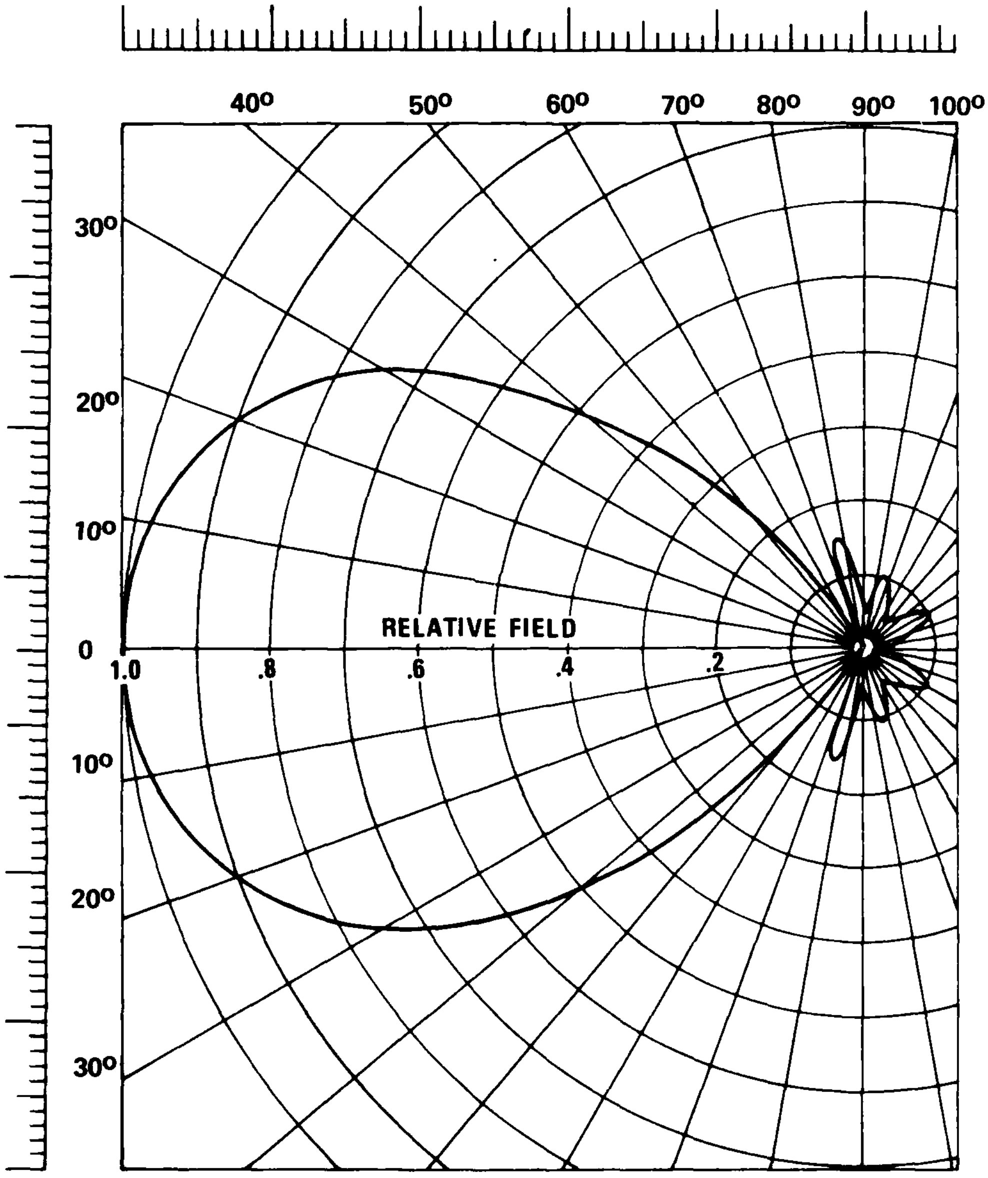


FIG 5

TYPICAL MEASURED HORIZONTAL PATTERN OF SINGLE TRAVELING WAVE ELEMENT

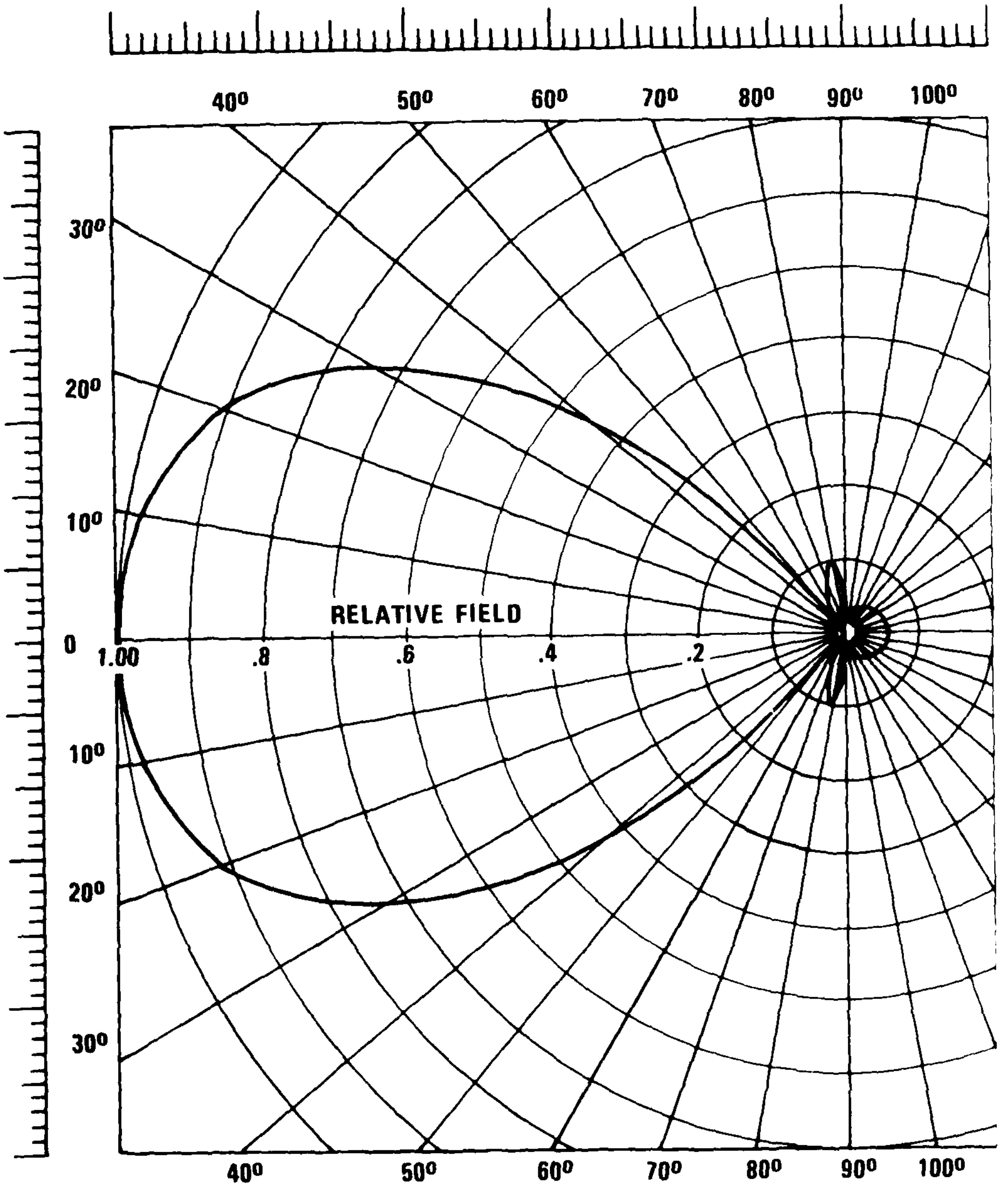


FIG. 6
TYPICAL MEASURED VERTICAL
PATTERN OF SINGLE TRAVELING
WAVE ELEMENT (FREE SPACE)

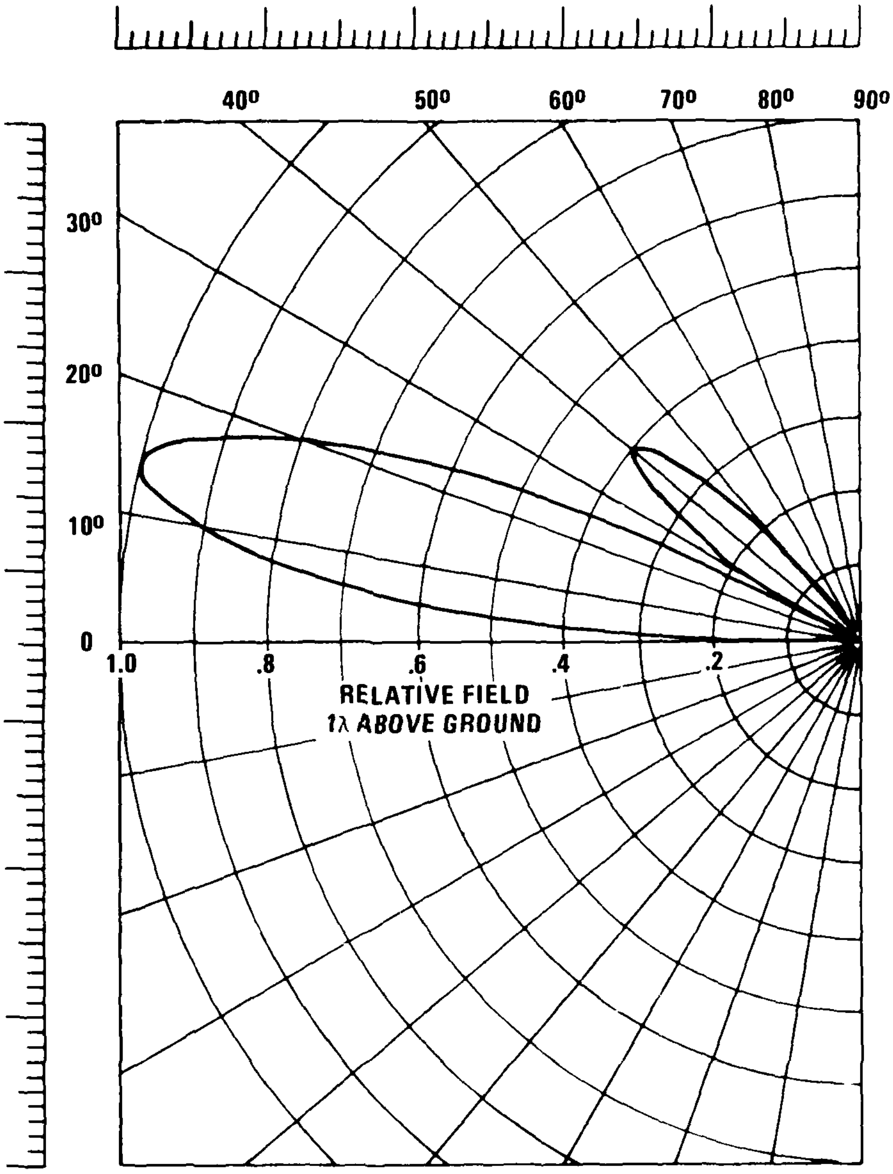


FIG. 7
TYPICAL VERTICAL PATTERN OF ARRAY

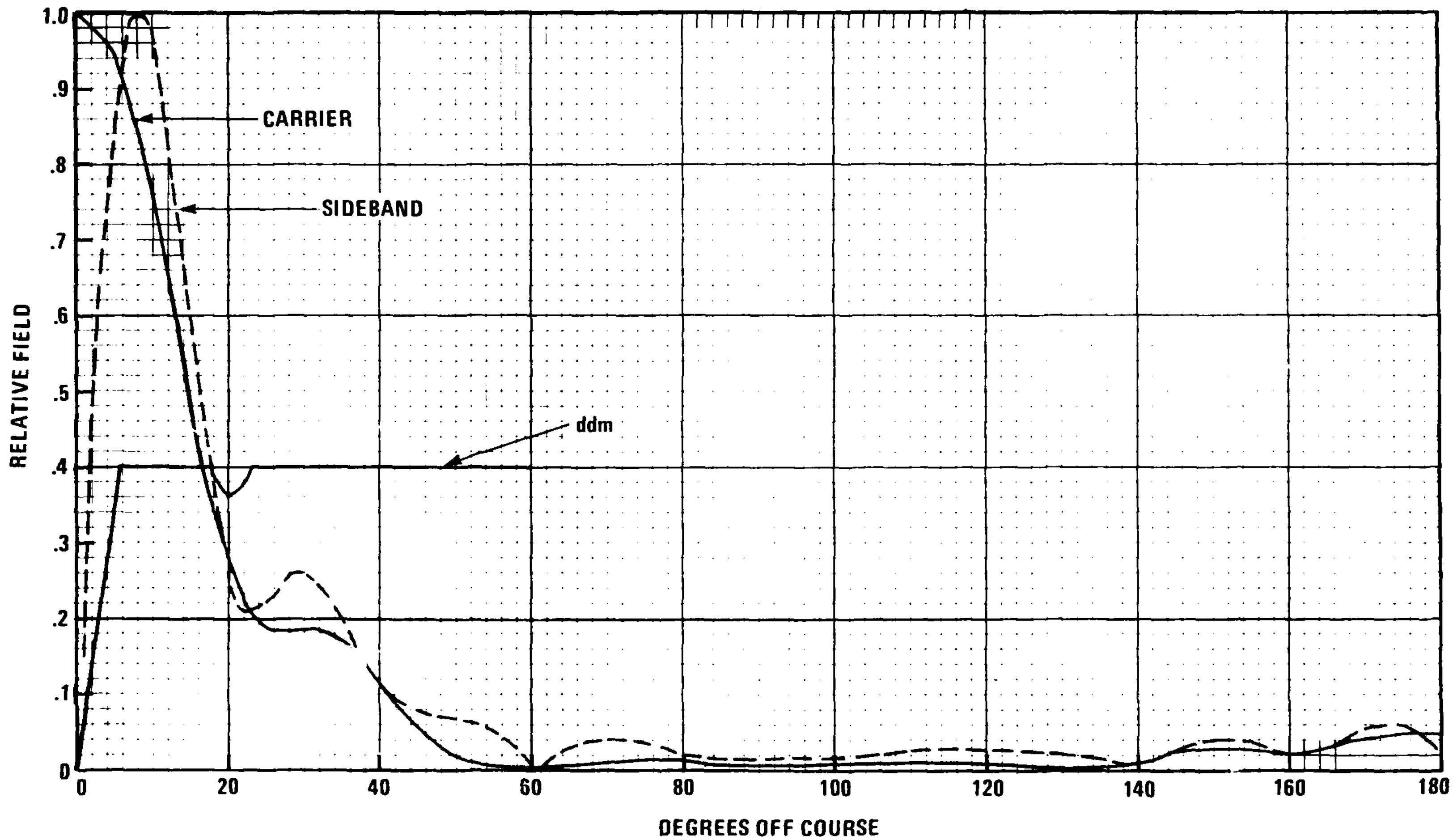


FIG. 8
TYPICAL
TYPE O ARRAY PATTERNS

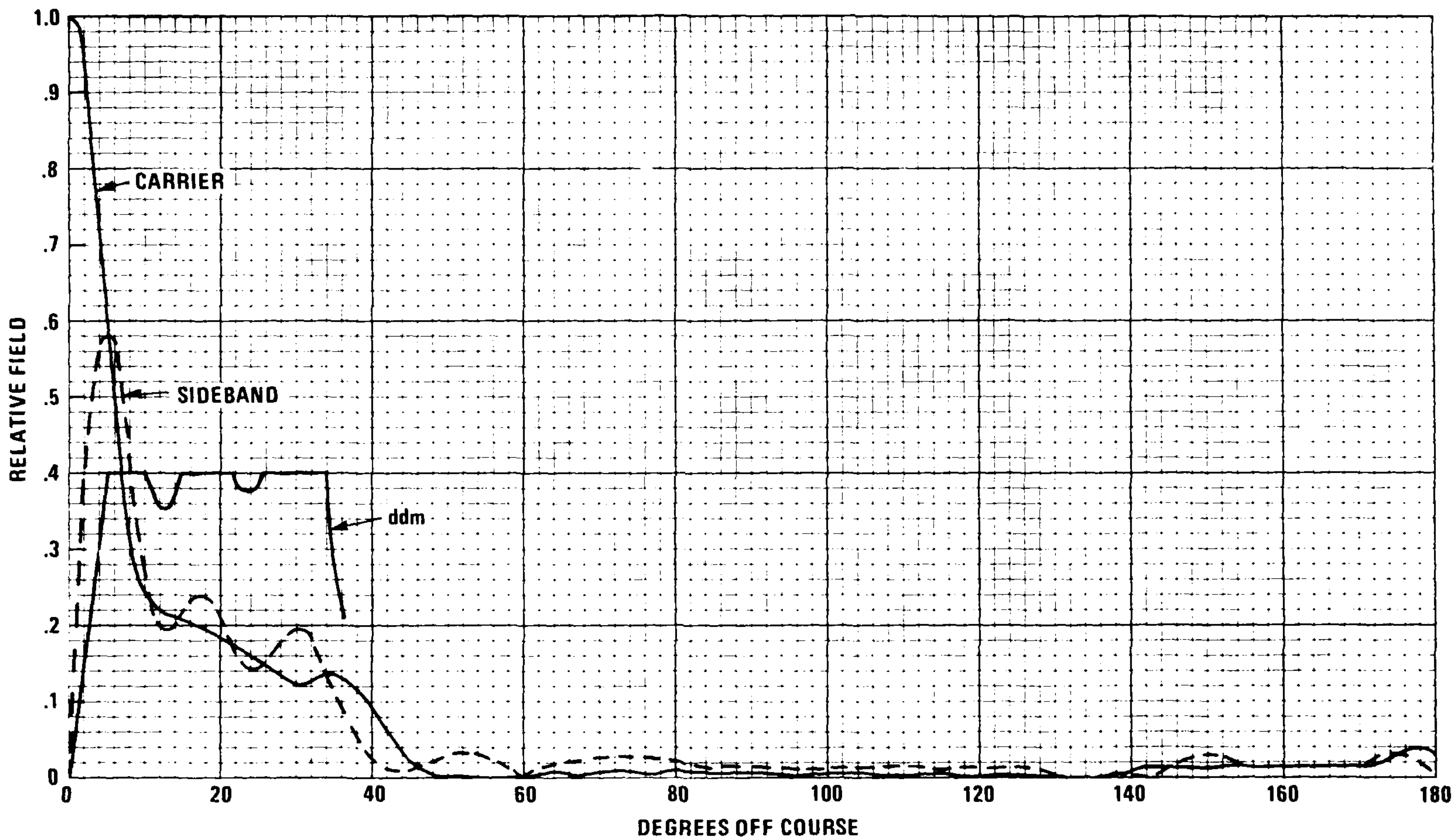


FIG. 9
TYPICAL
TYPE 1A ARRAY PATTERNS
4° cw

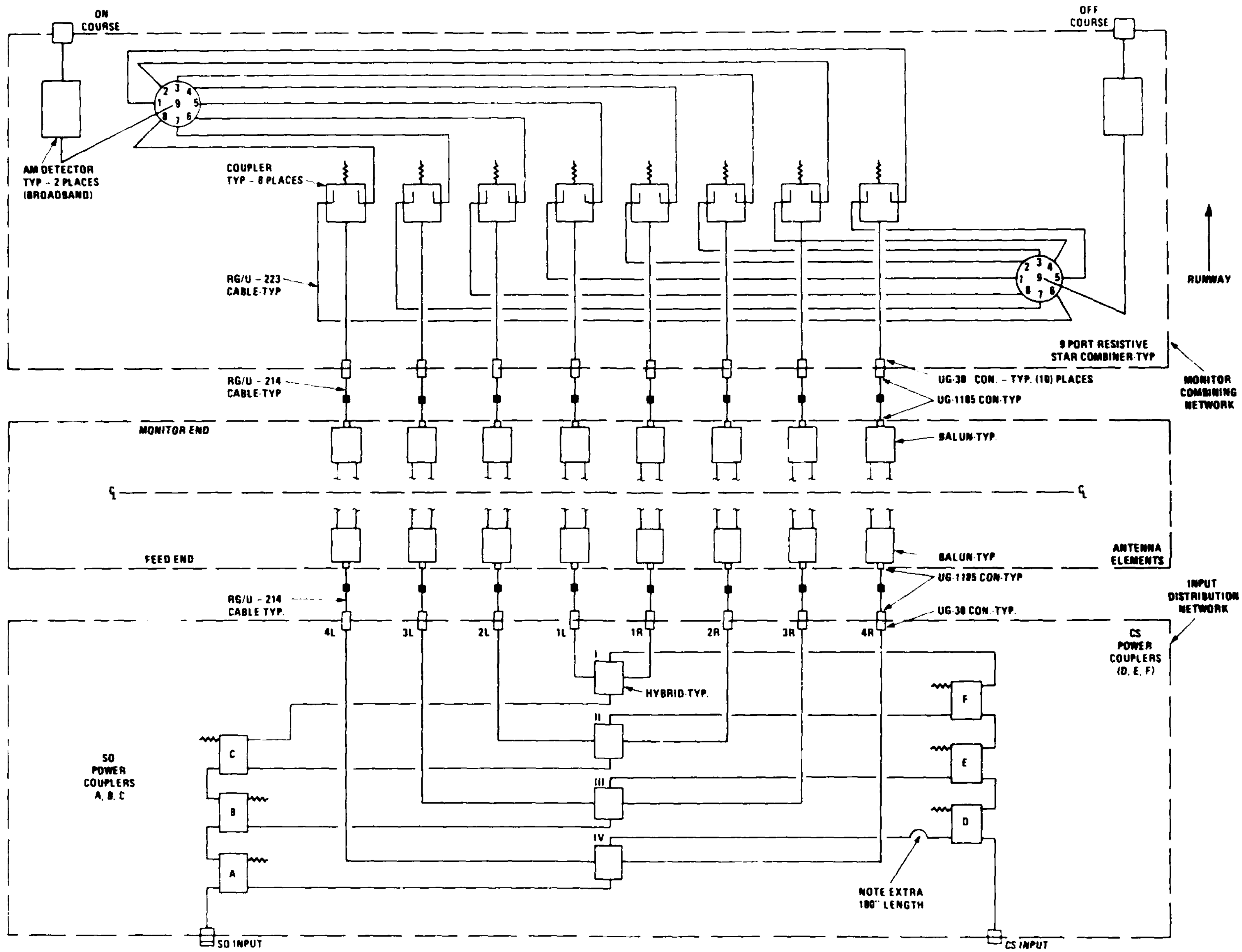
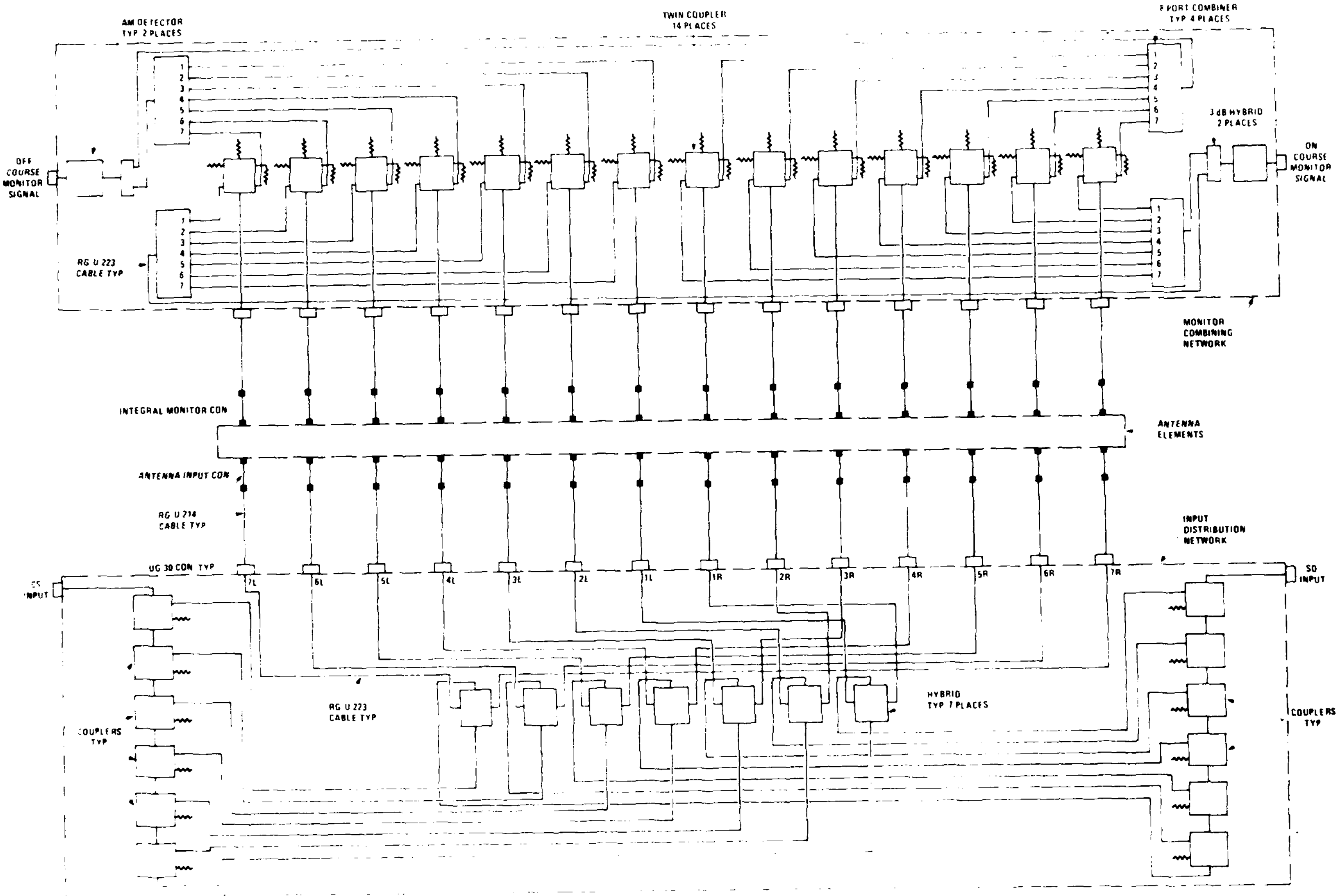


FIG 10
TYPICAL TYPE O ARRAY SCHEMATIC


AM DETECTOR
TYP 2 PLACES
TWIN COUPLER
14 PLACES
8 PORT COMBINER
TYP 4 PLACES
OFF
COURSE
MONITOR
SIGNAL
3 dB HYBRID
2 PLACES
ON
COURSE
MONITOR
SIGNAL
RG U 223
CABLE TYP
MONITOR
COMBINING
NETWORK
INTEGRAL MONITOR CON
ANTENNA
ELEMENTS
ANTENNA INPUT CON
RG U 214
CABLE TYP
INPUT
DISTRIBUTION
NETWORK
UG 30 CON TYP
CS
INPUT
SO
INPUT
7L
6L
5L
4L
3L
2L
1L
1R
2R
3R
4R
5R
6R
7R
RG U 223
CABLE TYP
HYBRID
TYP 7 PLACES
COUPLERS
TYP
COUPLERS
TYP

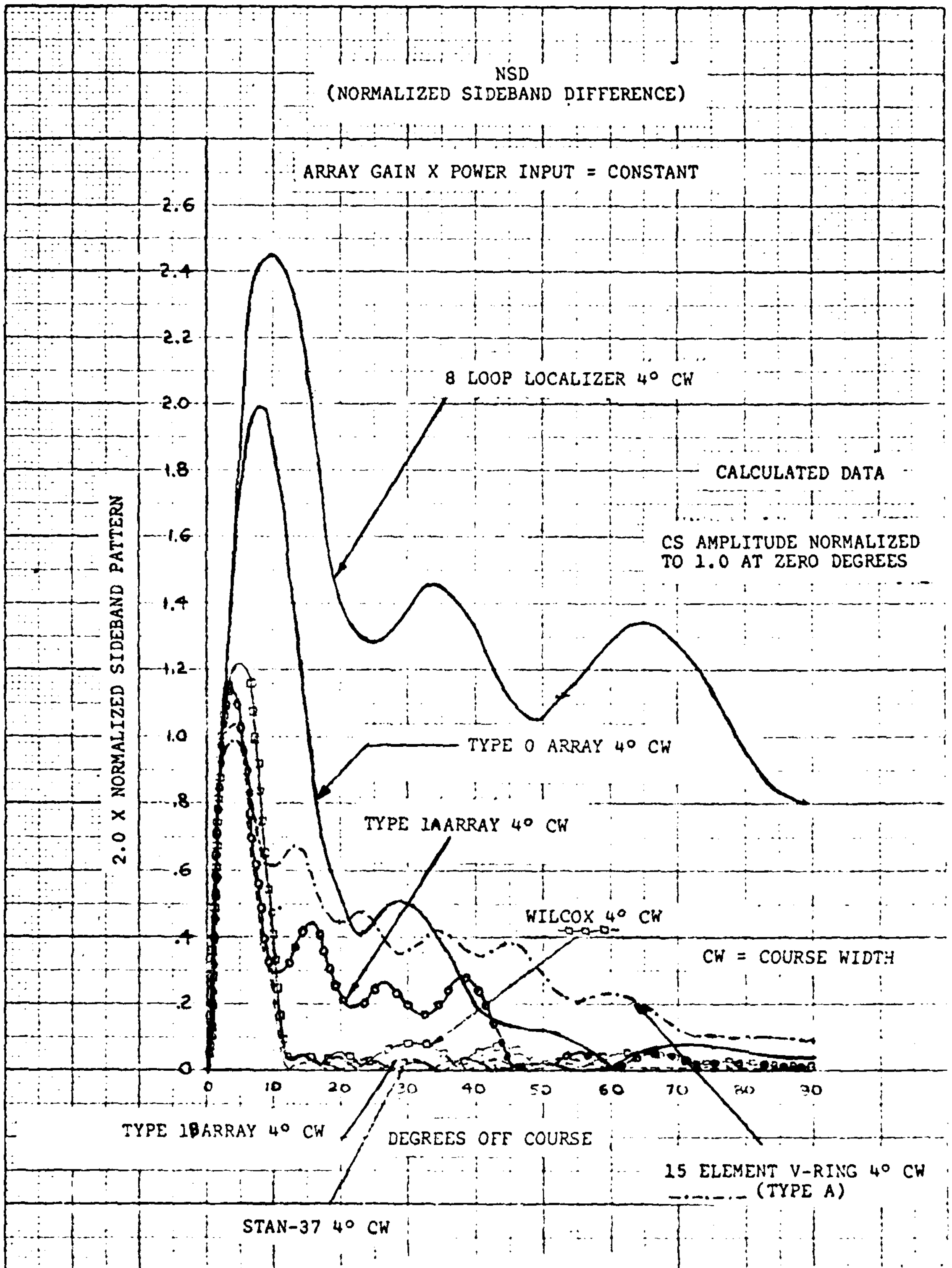
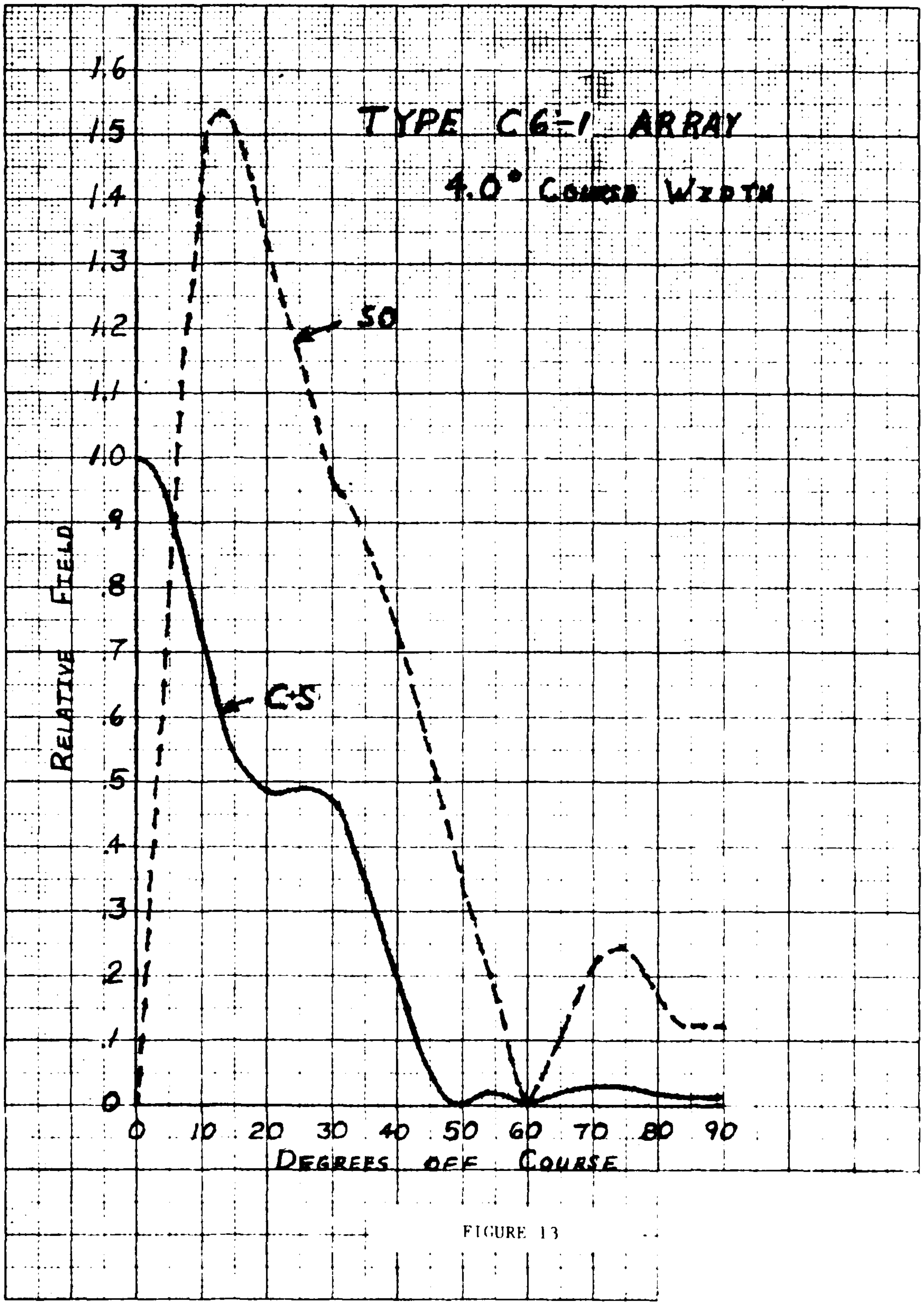

NSD
(NORMALIZED SIDEBAND DIFFERENCE)
ARRAY GAIN X POWER INPUT = CONSTANT
2.0 X NORMALIZED SIDEBAND PATTERN
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
.8
.6
.4
.2
0
8 LOOP LOCALIZER 4° CW
CALCULATED DATA
CS AMPLITUDE NORMALIZED
TO 1.0 AT ZERO DEGREES
TYPE 0 ARRAY 4° CW
TYPE 1A ARRAY 4° CW
WILCOX 4° CW
CW = COURSE WIDTH
0
10
20
30
40
50
60
70
80
90
TYPE 1B ARRAY 4° CW
DEGREES OFF COURSE
15 ELEMENT V-RING 4° CW
(TYPE A)
STAN-37 4° CW

FIGURE 12



TYPE CG-1 ARRAY
4.0° COURSE WIDTH
1.6
1.5
1.4
1.3
1.2
1.1
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
RELATIVE FIELD
50
C+5
0 10 20 30 40 50 60 70 80 90
DEGREES OFF COURSE

FIGURE 13

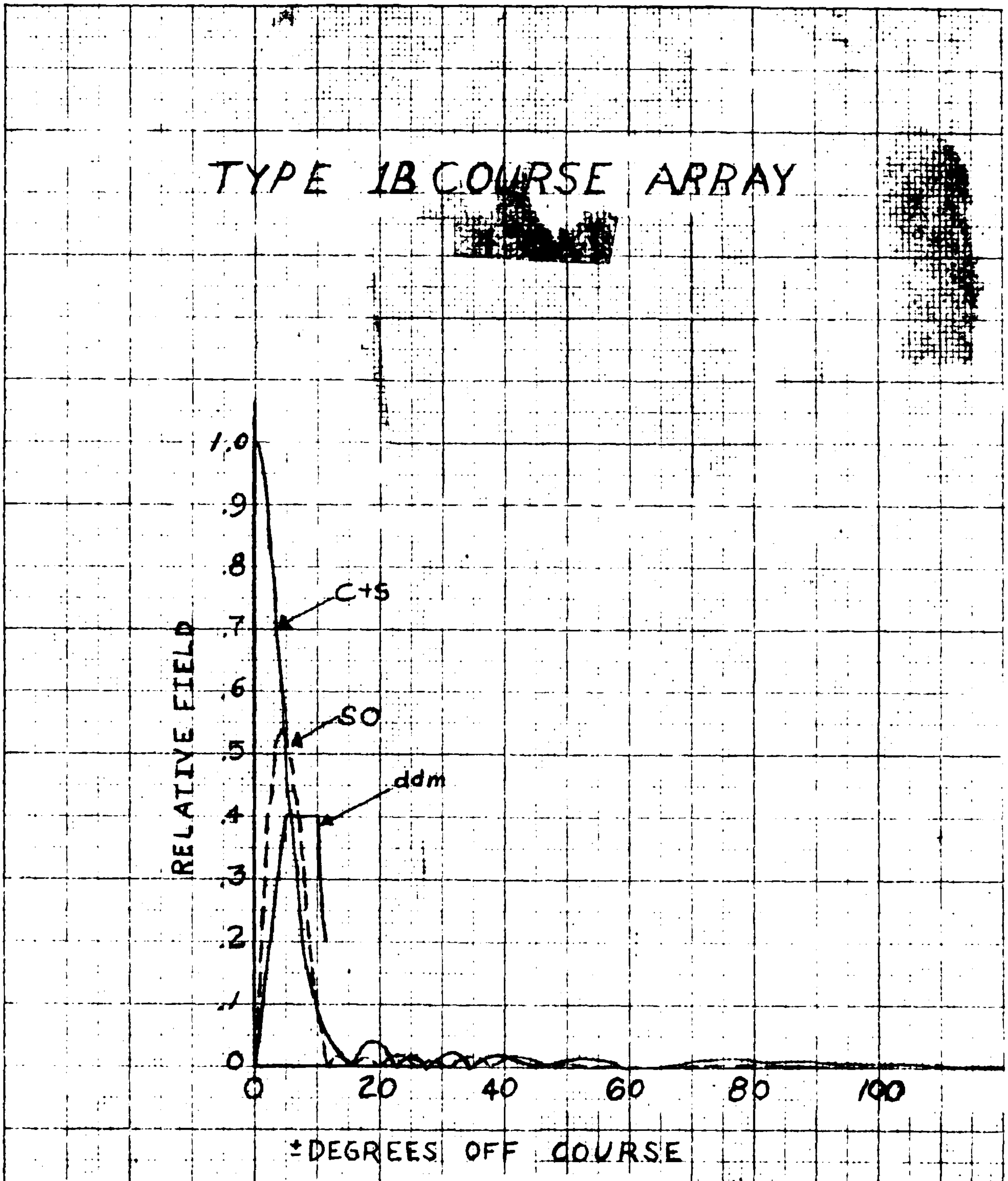
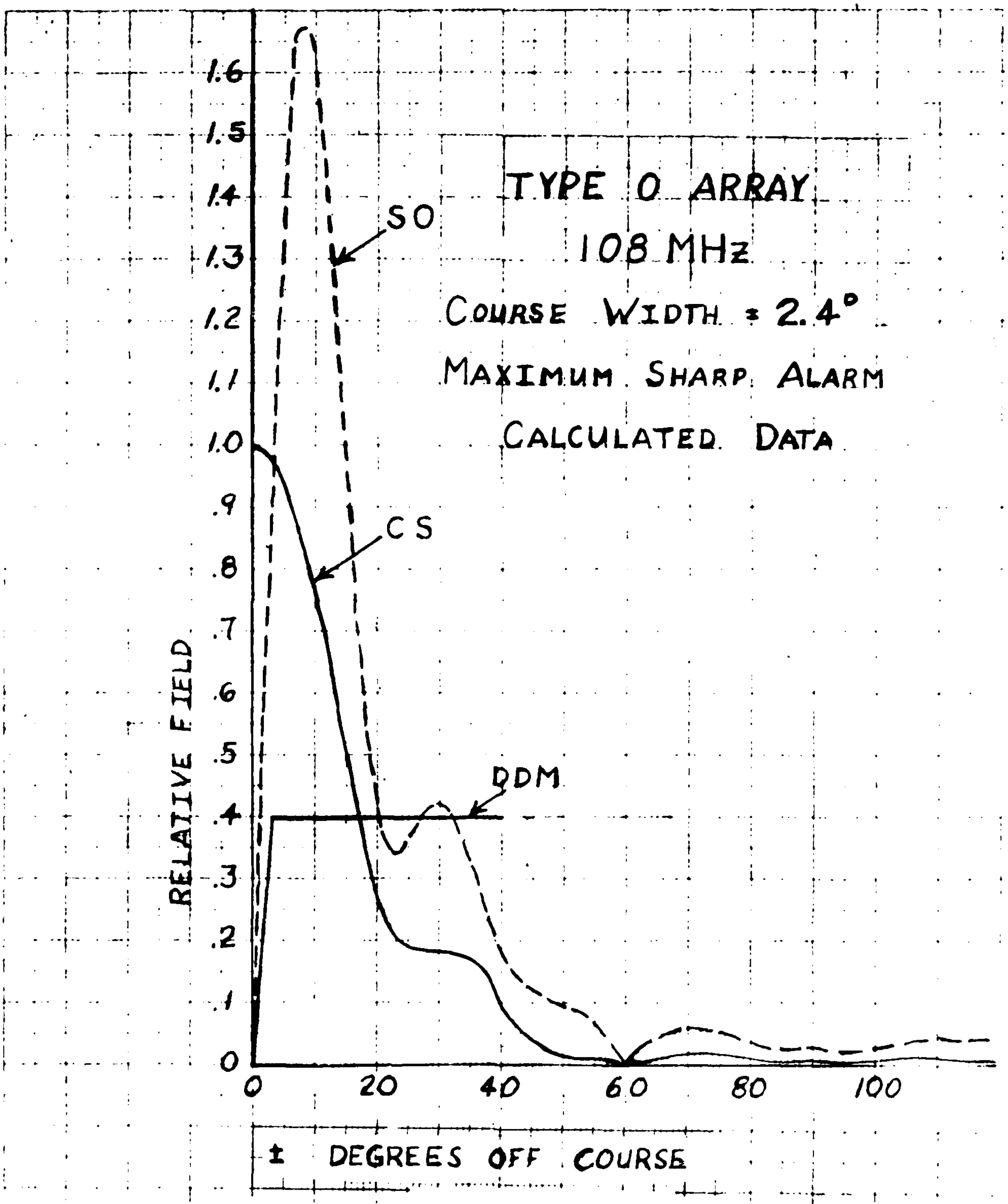

TYPE 1B COURSE ARRAY
RELATIVE FIELD
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
C+S
SO
ddm
0
20
40
60
80
100
±DEGREES OFF COURSE

FIGURE 14



TYPE O ARRAY
108 MHz
COURSE WIDTH = 2.4°
MAXIMUM SHARP ALARM
CALCULATED DATA
SO
CS
DDM
RELATIVE FIELD
1.6
1.5
1.4
1.3
1.2
1.1
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
0
20
40
60
80
100
± DEGREES OFF COURSE

FIGURE 15

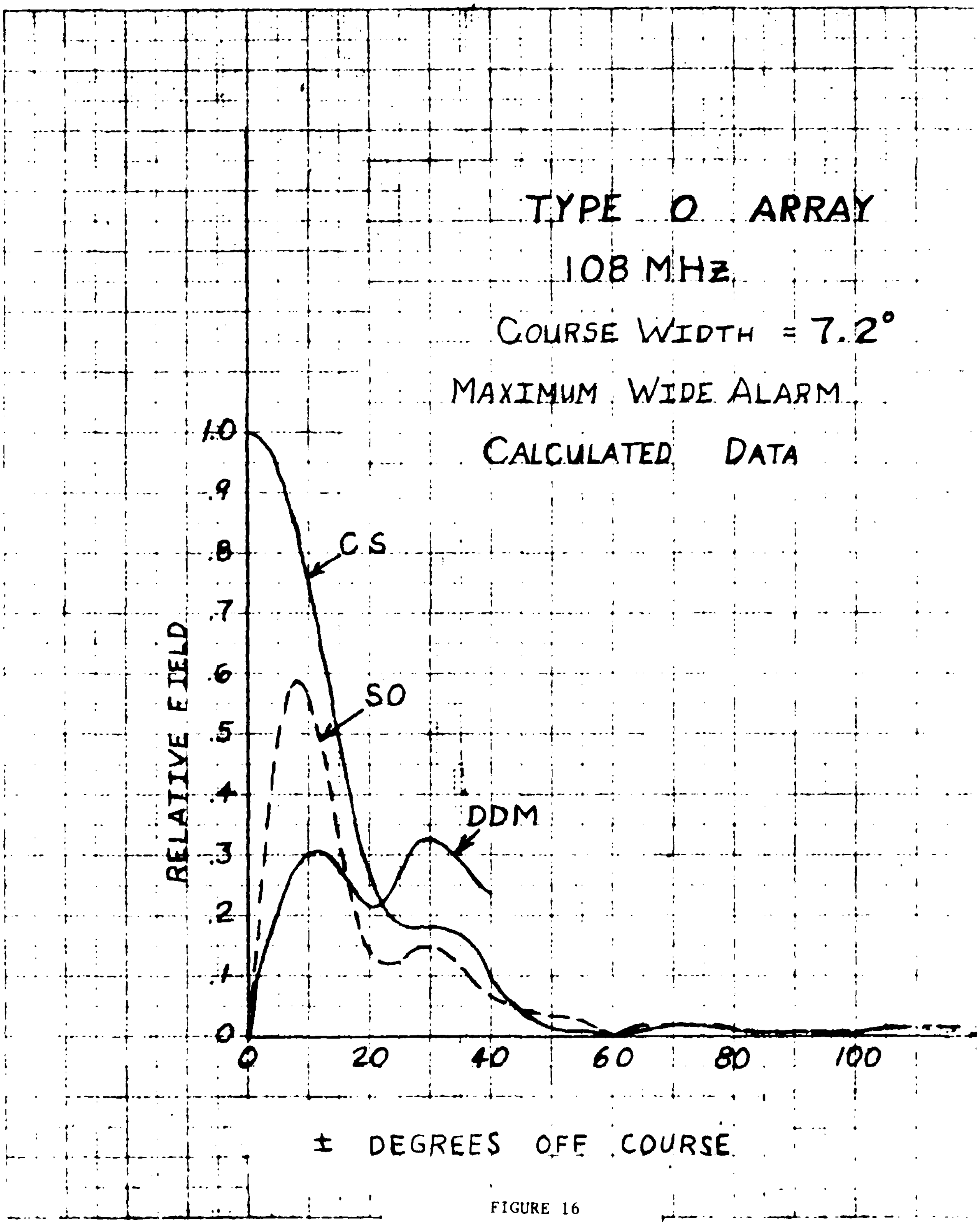

TYPE O ARRAY
108 MHz
COURSE WIDTH = 7.2°
MAXIMUM WIDE ALARM
CALCULATED DATA
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
RELATIVE FIELD
CS
SO
DDM
0
20
40
60
80
100
± DEGREES OFF COURSE

FIGURE 16

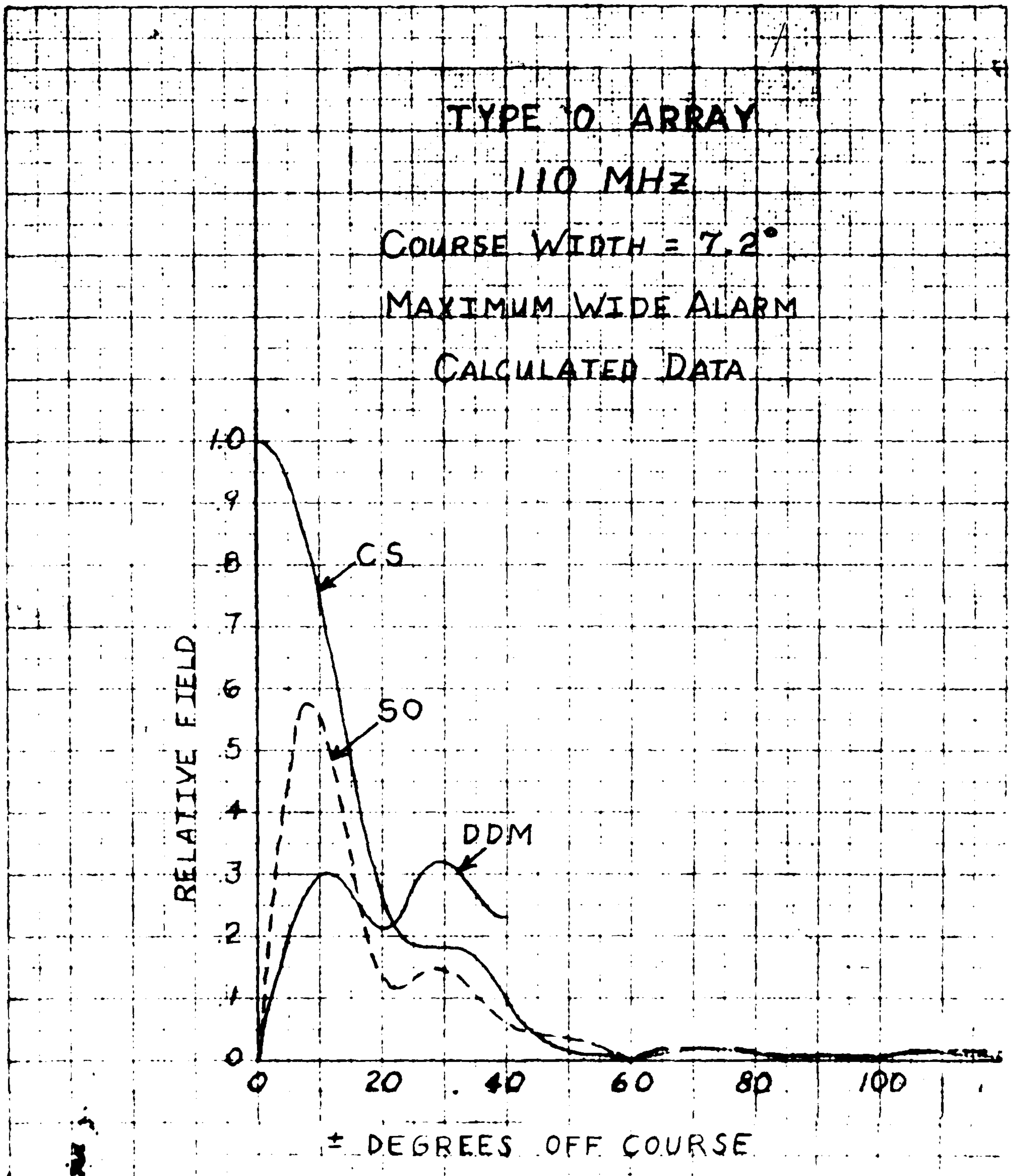

TYPE 'O' ARRAY
110 MHz
COURSE WIDTH = 7.2°
MAXIMUM WIDE ALARM
CALCULATED DATA
CS
SO
DDM
RELATIVE FIELD
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
.0
0
20
40
60
80
100
± DEGREES OFF COURSE

FIGURE 17

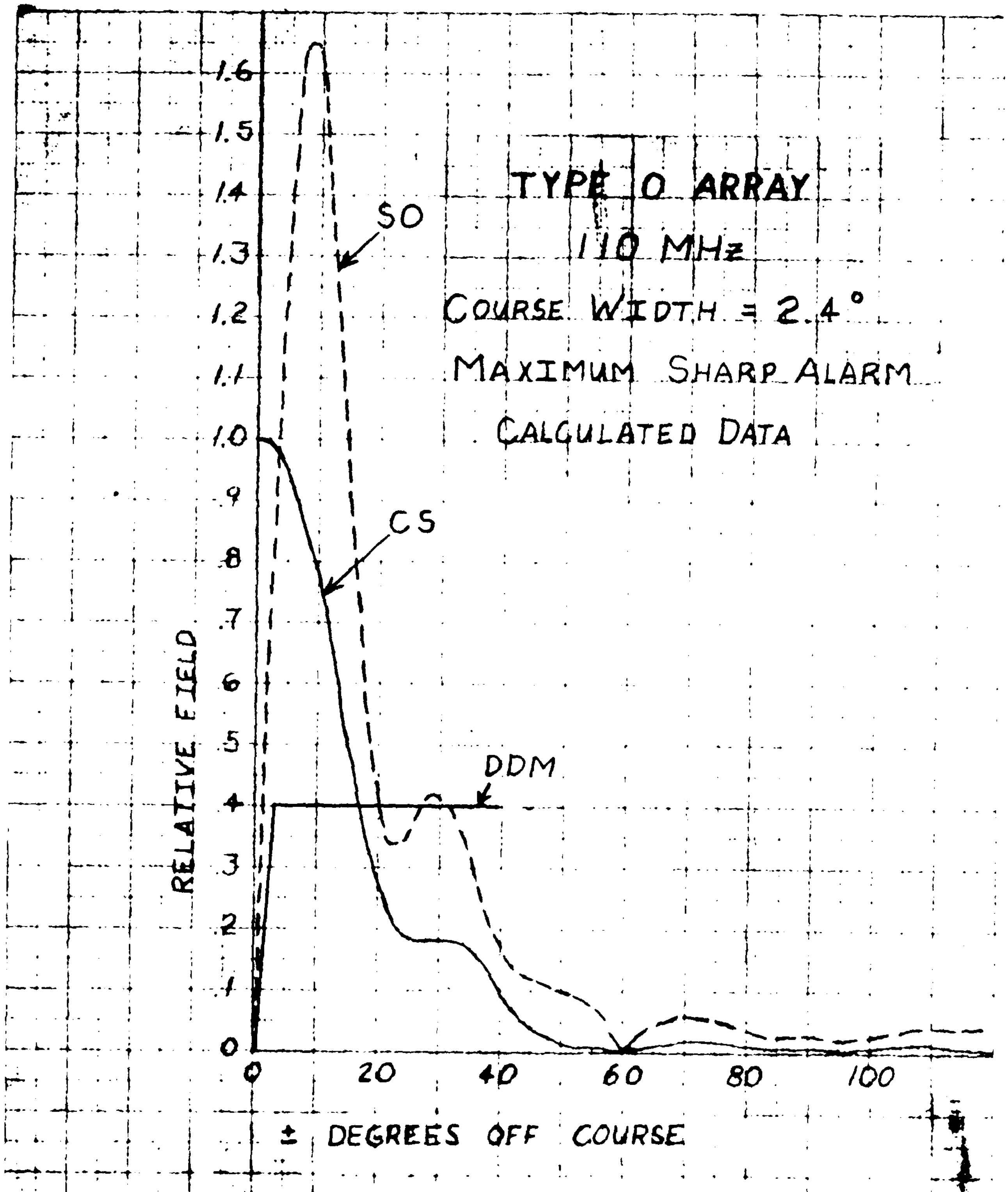
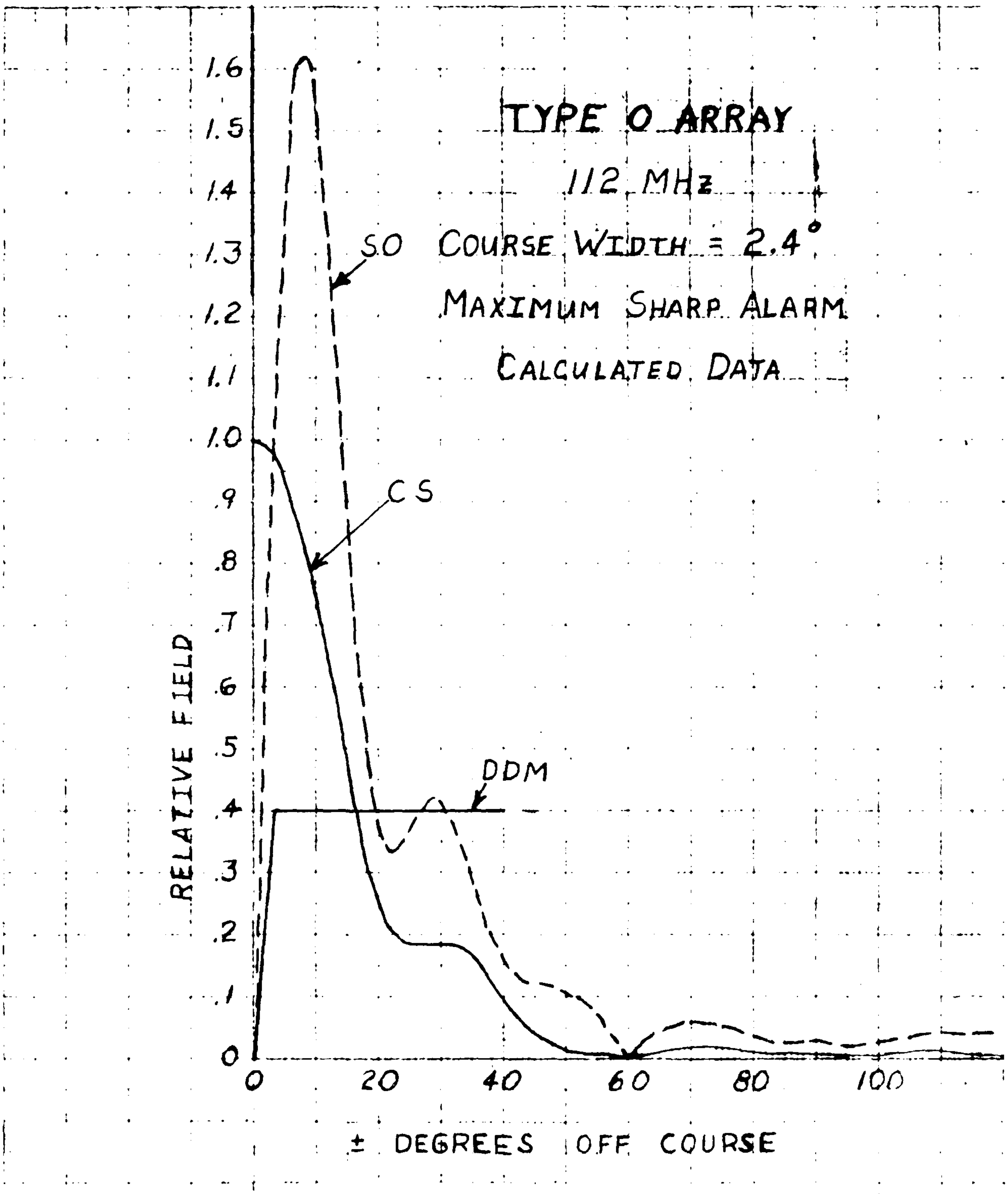

TYPE O ARRAY
110 MHz
COURSE WIDTH = 2.4°
MAXIMUM SHARP ALARM
CALCULATED DATA
SO
CS
DDM
RELATIVE FIELD
1.6
1.5
1.4
1.3
1.2
1.1
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
0
20
40
60
80
100
± DEGREES OFF COURSE

FIGURE 18



TYPE O ARRAY
112 MHz
COURSE WIDTH = 2.4°
MAXIMUM SHARP ALARM
CALCULATED DATA
SO
CS
DDM
RELATIVE FIELD
1.6
1.5
1.4
1.3
1.2
1.1
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
0
20
40
60
80
100
± DEGREES OFF COURSE

FIGURE 19

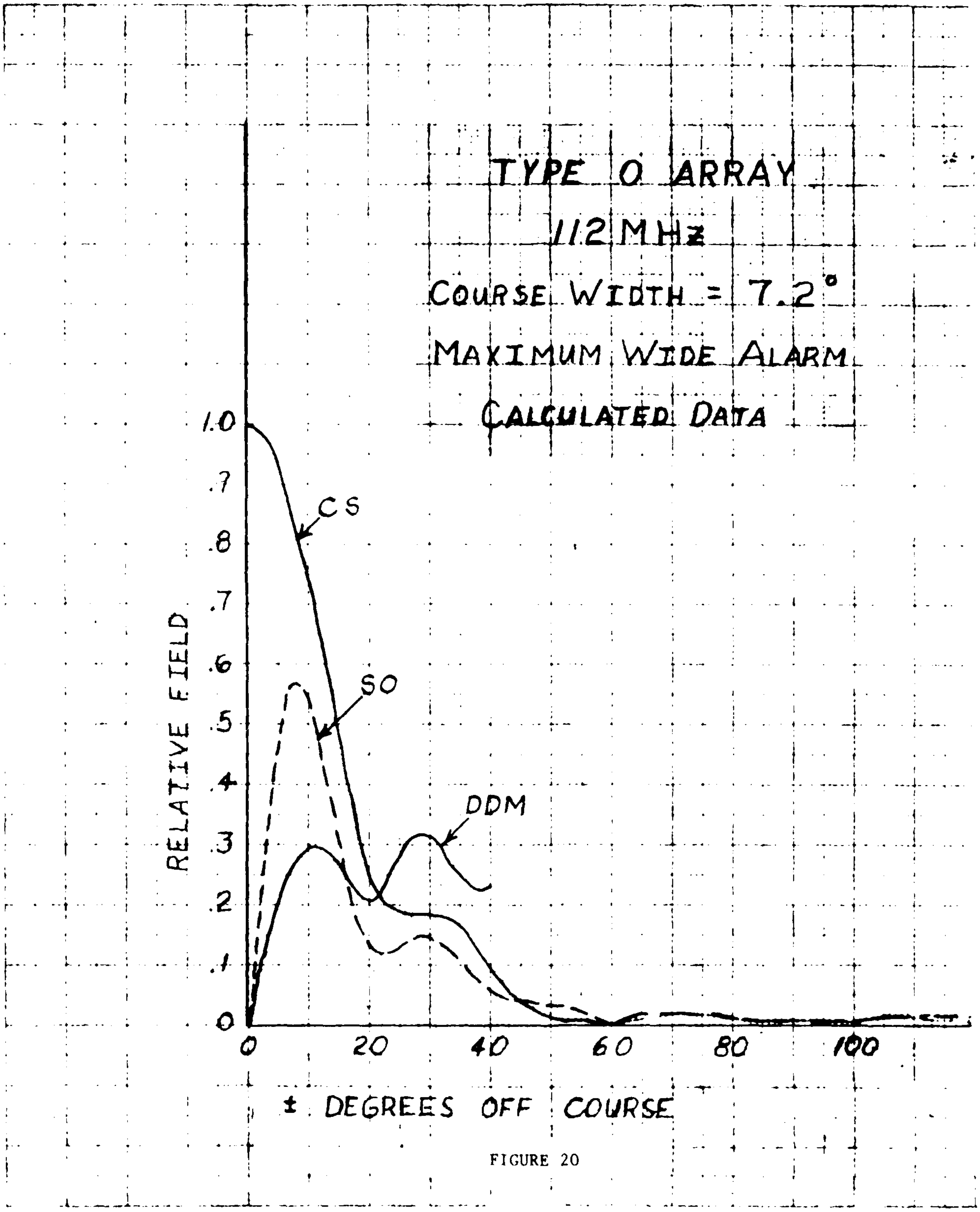

TYPE O ARRAY
112 MHz
COURSE WIDTH = 7.2°
MAXIMUM WIDE ALARM
CALCULATED DATA
CS
SO
DDM
RELATIVE FIELD
1.0
.8
.7
.6
.5
.4
.3
.2
.1
0
20
40
60
80
100
± DEGREES OFF COURSE

FIGURE 20

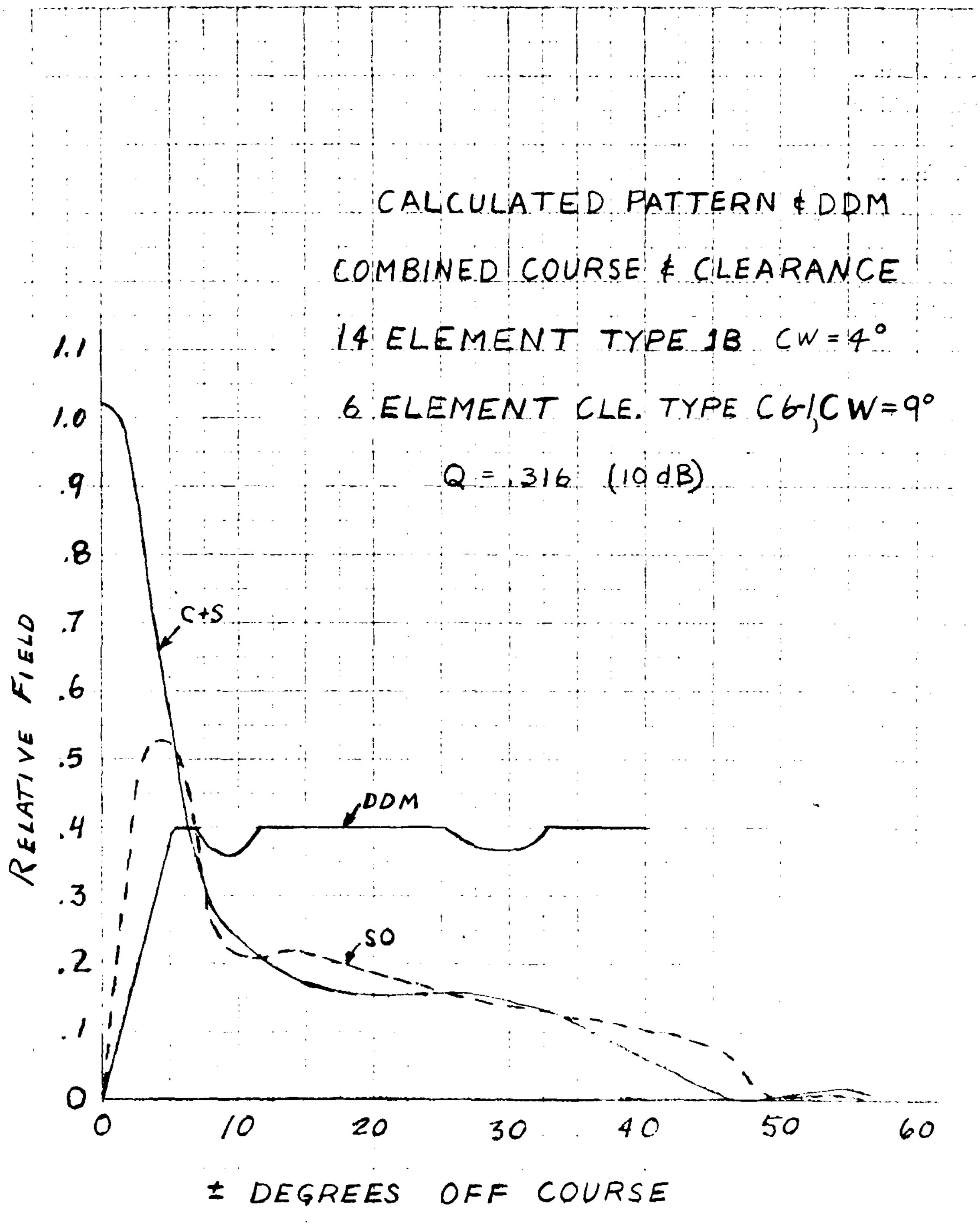

CALCULATED PATTERN & DDM
COMBINED COURSE & CLEARANCE
14 ELEMENT TYPE 1B CW = 4°
6 ELEMENT CLE. TYPE C6-1, CW = 9°
Q = .316 (10 dB)
RELATIVE FIELD
1.1
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
C+S
DDM
SO
0
10
20
30
40
50
60
± DEGREES OFF COURSE

FIGURE 21

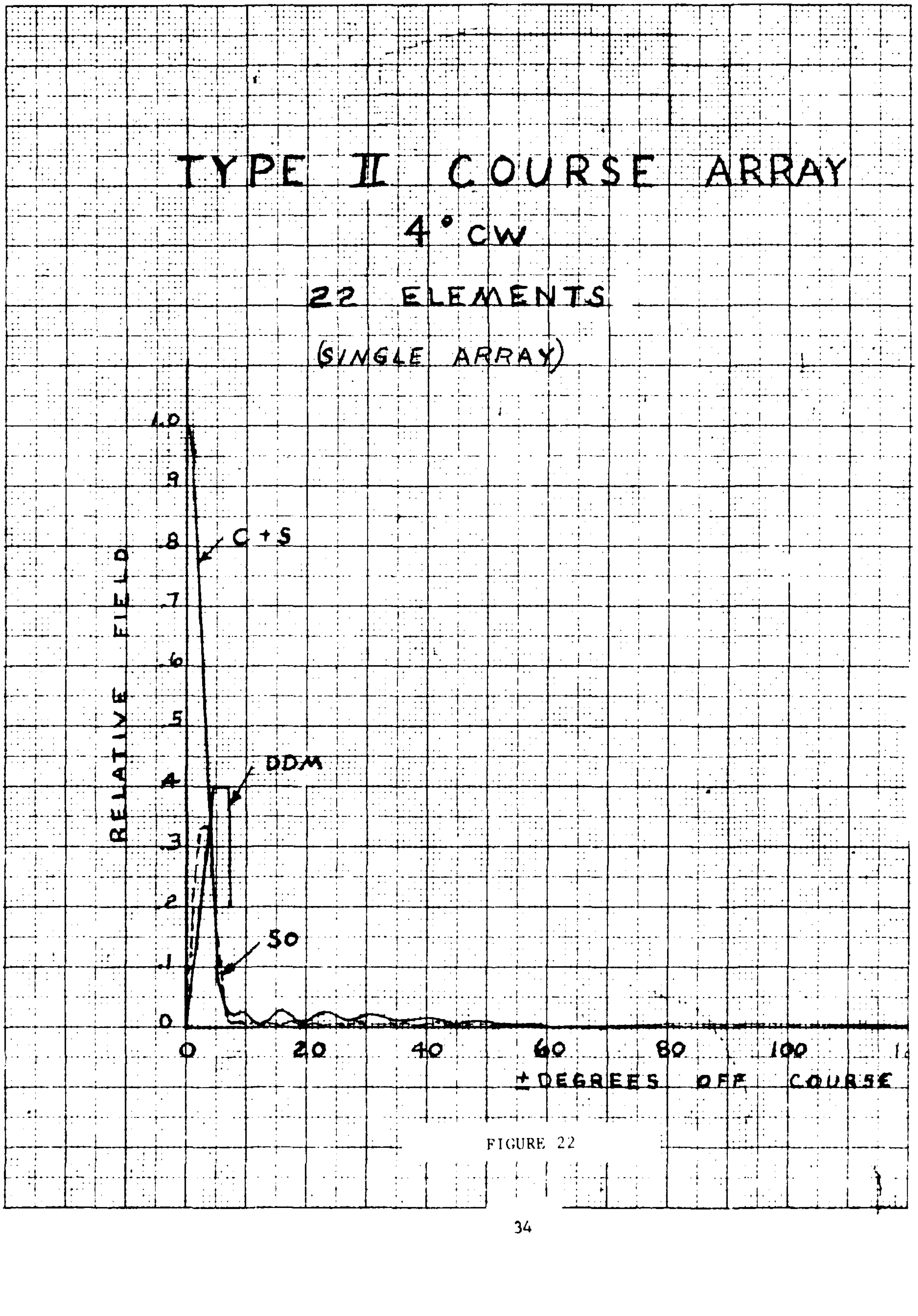

TYPE II COURSE ARRAY
4° CW
22 ELEMENTS
(SINGLE ARRAY)
RELATIVE FIELD
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
C + S
DDM
SO
0
20
40
60
80
100
± DEGREES OFF COURSE

FIGURE 22

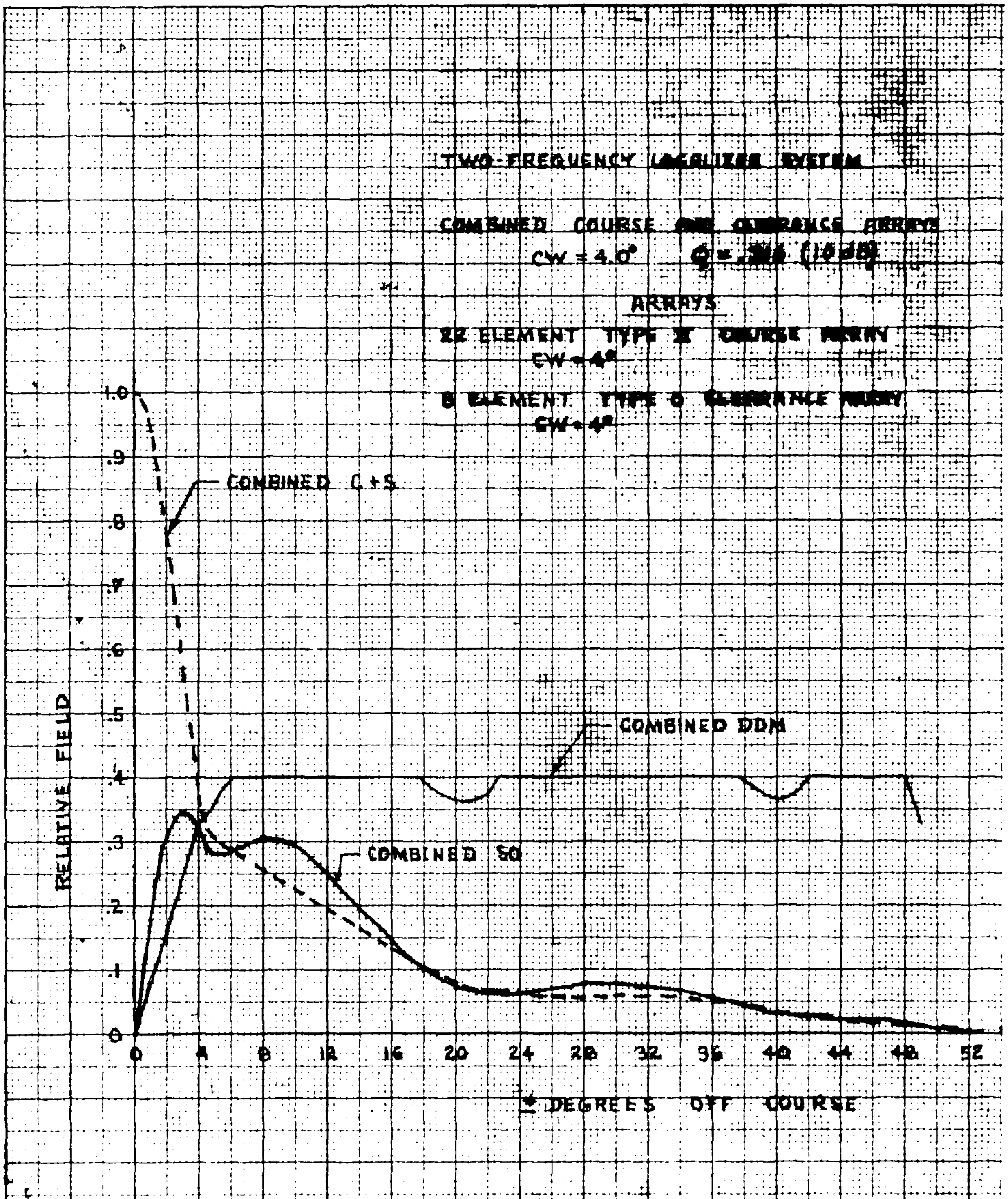

TWO-FREQUENCY SYSTEM
COMBINED COURSE
CW = 4.0°
ARRAYS
ELEMENT TYPE
ELEMENT TYPE
COMBINED C+S
COMBINED DDM
COMBINED SO
RELATIVE FIELD
0
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0
0
4
8
12
16
20
24
28
32
36
40
44
48
52
± DEGREES OFF COURSE

FIGURE 23

APPENDIX

SITE TEST OF THE TYPE 2 LOCALIZER SYSTEM

AT BOEING FIELD INTERNATIONAL

AUGUST 22 TO SEPTEMBER 7, 1972

JANUARY 22, 1973

ANDREW ALFORD CONSULTING ENGINEERS
120 CROSS STREET, WINCHESTER, MASSACHUSETTS 01890

SITE TEST OF THE TYPE TWO LOCALIZER AT BOEING FIELD INTERNATIONAL AIRPORT ON AUGUST 22 TO SEPTEMBER 1, 1972

Summary of Activity Schedule

1.	Aug. 10 - 11	Pack arrays and equipment at NAFEC for delivery to Boeing Field via truck.
2.	Aug. 15	Equipment arrives at Seattle.
3.	Aug. 19 - 22	Erect temporary support decks for arrays.
4.	Aug. 23 - 24	Install base angles and level support structures for 22 element array and 8 element array.
5.	Aug. 24	Flight checks of BFI commissioned facility without test arrays erected in front.
		Erect type 0 array (8 element array).
		Flight check of BFI commissioned facility with type 0 array erected in front of waveguide array approximately [illegible] feet.
6.	Aug. 25	Erect 22 element array approximately 225 feet in front of waveguide array.
		Flight check of BFI commissioned facility with 8 element array and 22 element array erected.
7.	Aug. 28 to Sept. 1	Flight tests of type 2 localizer, type 1B localizer, type 1A localizer, type 0 localizer and type [illegible] localizer.
8.	Sept. 6 - 7	Dismantle test arrays, pack in truck for return shipment to NAFEC.
9.	Sept. 12	Arrays arrive at NAFEC.

Summary of Test Results

The results of the recently conducted tests of the type 2 localizer array on runway 13[illegible] at Boeing Field International show that:

1. Course structure of CAT III quality was obtained.
2. Minimum clearances with the type two course array operating in wide alarm ([illegible].2°) was 240 micro-amperes.
3. Usable distance for the Boeing Field site was obtained using 3.0 watts input to the 8 element clearance array, and [illegible] watts input to the 22 element course array.
4. Flight tests of the type 1B localizer, the type 1A localizer, the type 0 localizer, the type C6-1 localizer, and the [illegible] commissioned facility were also conducted. Data on these tests is included in the report.
5. Satisfactory results were also obtained with the clearance array moved to 75 feet behind the course array.
6. Special tests to show the effect of moving vehicles 75 feet in front of the course array were conducted. The data [illegible] that the effect of the station wagons driven [illegible] the runway at distances around 75 feet in front of the array was very small.
7. Vertical polarization effect for all arrays tested was found to be well within CAT II requirements.

TYPE 2 LOCALIZER SITE TEST AT BOEING FIELD INTERNATIONAL AIRPORT

A. Introduction

In accordance with the requirements of FAA Contract DOT-FA-72WA-2253, we have tested the type 2 localizer at a "problem site." The airport which was chosen was Boeing Field International Airport, Seattle, Washington. The localizers were erected on runway 13R for the tests.

The recent series of tests were conducted between August 23, 1972, and September 1, 1972.

By arrangements made by the FAA, the arrays were transferred to Boeing Field from NAFEC, and returned to NAFEC, by truck. Temporary wooden decks on which to erect the arrays and engineering assistance was provided by the FAA Northwest Region.

The assembly of the arrays was performed by Alford personnel assisted by personnel from FAA Washington, D.C. and Seattle, Air Force, and the Texas Instruments Company. Flight checks were coordinated by engineering personnel from the Northwest Region.

Flight tests were conducted by WE-FIFO-3 SEA. FAA Aircraft N[illegible], a DC-3, was used for all tests. FAA personnel from the Airway Facility Sector, Seattle, Washington also assisted in the erection of the arrays as well as participating in the test of the arrays. The cooperation and assistance during the tests by FAA personnel and non-FAA personnel was considerable. A list of the personnel participating in these tests is given on the last page of this report.

The tests are believed to have been successful and have provided much useful additional operating information on the family of arrays designed under the FAA Contract. A substantial portion of the measured data has been included in this report. A complete list of all flight tests is given in Table I.

B. Test Location

The tests of the type 2 localizer at Boeing Field were performed with the arrays installed in line with runway 13R. Xerox copies of photographs, Dwg. A332-5002 and 332-5003 show the two arrays erected at Boeing Field International (BFI). Dwg. 332-5002 shows the 22 element type 2 course array, and Dwg. 332-5003 shows the eight element clearance array.

The arrays were installed on temporary wooden decks. These decks consisted of 4" X 4" timbers and 2" X 10" X 12'planks. The temporary wooden decks were assembled directly on the ground and were leveled as required. The erection, leveling and aligning of the temporary decks was coordinated and performed by FAA personnel.

The ground between the BFI commissioned facility and the stop end of runway 13R is reasonably flat and level so that the height above ground of the two arrays was approximately the same. The height of the radiating elements above ground was approximately [illegible] 1/2 feet. There were no permanent obstructions located between the test arrays and the stop end of the runway.

The test arrays were initially erected in front of the BFI commissioned localizer as shown on Dwg. A332-5001B. Tests were also made with the eight element clearance array moved forward so that the

spacing between the course array and the clearance array was approximately 75 feet. This condition is shown by a dashed line on Dwg. A332-5061B.

To move the 2 element clearance array forward, the temporary wooden platform was disconnected at the center of the deck and each half of the array was carried forward as a whole. The temporary wooden deck was bolted together again at the new location and the array was made reasonably level.

No attempt was made to realign the array very accurately.

The alignment and the centering of the eight element array with respect to runway centerline was done by tape measure and by eye. For a clearance array application, and for the tests that we were making, there was no need to locate this array with any greater precision.

C. Test Considerations

1. Site Selection

The selection of Boeing Field as the location for the type 2 localizer tests was made on the basis of the following considerations:

a. Reflections from hangars and the surrounding hillsides result in CAT I course quality even with the standard FAA wave guide localizer. (Boeing Field is indeed a problem site that would require the type 2 localizer if any upgrading of performance category was desired.)

b. The airport handles little of large jet traffic so that the delays and interference with the test schedule would be small. (This was indeed the case. Except for two or three landings

and take offs by "large" jets, no delays due to other aircraft were encountered. Furthermore, it is believed that our testing did not result in any delays of traffic or inconvenience to the airport.)

c. As an additional benefit, the FAA Flight Test Operations WE-F100-3-[illegible] are based at Boeing Field. (This was very convenient because it provided more time to arrange and discuss test schedules and test results.)

2. The Arrays - Table 1.

The testing included the flight check of the commissioned facility and of all presently considered "standard" combinations of the new family of ILS arrays. A complete list of the flight tests is given in Table 1, sheets 1 through 5.

Because of the fact that all of the ILS arrays [illegible] are constructed [illegible] the same radiating element and because the arrays [illegible] designed around a common center core of elements, any array [illegible] constructed by adding to or by subtracting from an existing array. The array elements are individually [illegible]. For example, with the 22 element course array erected, [illegible] the 22 element distribution network and replace it with the [illegible] distribution network connecting it to the 14 innermost elements of the [illegible] element array. There is no need to take down the remaining elements [illegible] there is practically no interaction between the elements. In this way, [illegible] can quickly construct and test the 14 element course array [illegible] the type 1B localizer. [illegible] the same 14 innermost elements, one can also use a [illegible] type of 14 element distribution network and obtain the [illegible] 14 element type 1A array. [illegible]

continued and the innermost 8 elements can be connected as the self-clearing type 0 array or as the 8 element clearance array (same as the type 0 array) used with the 22 element course array in the type 2 localizer. As a final degree of flexibility, at this time, one can use just the innermost 6 elements of the larger array and with the six element distr[illegible] the type CF-1 array. The type CF-1 array is normally used as the clearance array in the type 1B localizer.

At Boeing Field, a complete type 2 localizer consisting of a 22 element course array and an eight element clearance array were erected. The type 1B localizer was tested using the inner 14 elements of the 22 element array and the inner six elements of the eight element array. The type 0 array and the type CF-1 array were tested alone using the 8 element array. The type 14 array was tested using the innermost 14 elements of the 22 element array. The extra unexcited elements which result when smaller arrays are tested by exciting the inner elements of a larger array were left terminated in 50 ohm loads. The test results do not indicate any distortion of the RF patterns for the smaller array combinations as a result of the extra elements being erected.

Dwg. A3[illegible] shows some of the combinations of arrays which can be erected with the present family of arrays. Other combinations, such as, for example, 14 element clearance array with either a 14 element course array, or a 22 element course array may have [illegible] at [illegible] difficult sites. Still other variations would allow the clearance array to be placed either in front of the course array or to the rear

of the course array. The distance "d" shown in Dwg. A8[illegible] [illegible] on the test [illegible] at Boeing Field, would [illegible] 78 feet. The Boeing Field [illegible] test [illegible] include [illegible]. It is not [illegible] effect, if any, [illegible] on the [illegible].

The calculated [illegible] patterns for the individual arrays [illegible] shown on Dwgs. A[illegible], [illegible], [illegible], [illegible], and [illegible]. In addition, the calculated patterns for the [illegible] and the [illegible] localizer systems are shown on Dwgs. B[illegible]-[illegible] and [illegible]. The patterns shown on Dwgs. [illegible] and [illegible] were calculated for a [illegible] ratio of the course array [illegible] field to the clearance array field.

Prior to any flight tests of the traveling wave arrays, all of the antennas and cables were checked at low power using an Alford Type [illegible] Impedance and Transfer Characteristic Plotter. The data taken on all antenna elements, except for [illegible], [illegible], was essentially the same. Prior to exciting any of the arrays for [illegible] the phases and magnitudes at the outputs of the distribution network were measured. Some of the data, on the 22 element and the eight element arrays, was measured at the output ends of the [illegible] with the arrays connected. The magnitudes and phases of the [illegible] delivered to the elements of the [illegible] array, the 14 element [illegible] and to the type 1A array were measured at the output of the respective distribution networks. The measured data was in reasonable agreement with previously [illegible] the same kind. A portion of the [illegible] data is shown in Dwgs. A[illegible] 50[illegible], -5006, -5007, -5008, -[illegible], -5010, -5011, -5012, -[illegible], and -5014.

3. The Transmitter

The transmitter used for the tests was the BFI facility transmitter. For the most part, all of the flight tests on the developmental [illegible] arrays was made using transmitter No. 1. Tests made on the BFI facility were made using both transmitters. The percentage of modulation, as determined by periodic checks throughout the test period, was maintained between 19.5% to 2[illegible].5%.

The BFI facility was put back on the air every day following our flight checks. Connection to the BFI facility was made through a junction box located near the eight loop array and a second junction box located near the waveguide. The available power at these points was approximately 43 watts for the clearance array and 91 watts for the course array. Required cable lengths, attenuators and adjustable power dividers to reduce these powers to the desired levels for the developmental arrays was planned for and supplied by AACE so that no transmitter changes or transmitter adjustments were required.

D. BFI Commissioned Facility Considerations

The commissioned localizer facility at Boeing Field International consists of an FAA waveguide course array and an 8 loop clearance array. The approximate geometrical relationship between these arrays, the test arrays, and the runway 13R is shown in Fig. A5-[illegible]. Approximate input power at the course array is 91 watts and the approximate input power at the clearance array is 4[illegible] watts. Nominal course width for this facility is approximately 4.[illegible]°. The facility was commissioned in January, 19[illegible]. At that time, the facility was restricted in use to [illegible] of the front course. The facility in December of 19[illegible] was further restricted in use to

±35° of the front course. The restriction is due to low clearances which occur around 40° on the 90 ~ side of the runway. It is not known what occurred to initiate the additional restriction. The clearances on the 150 ~ side of the course look acceptable out beyond 60°, which is the extent of the data taken at a 1500 foot altitude. Other clearance data taken at a [illegible] foot altitude would indicate that acceptable clearances on the 150 ~ side [illegible] even be expected out to [illegible] the front course [illegible] altitude for the [illegible] 1500 feet above [illegible].

The clearance [illegible] on both the 90 ~ and 150 ~ sides of the course do contain considerable scalloping, approximately 50 μa on the 90 ~ side and approximately 60 μa on the 150 ~ side. This scalloping is believed to be due to buildings located [illegible] in one case, and from the very extensive [illegible] the 90 ~ side. The scalloping on the 150 ~ side of the course [illegible] approximately [illegible] from the front course and [illegible] the 35° authorized sector. The scalloping at the 90 ~ side of the course is most evident around [illegible] from the front course and out beyond approximately 35° to 50° from the front course. In the other sectors, on the 90 ~ side of the course, between approximately [illegible] to 40° of the front course, the scalloping appears to be depressed because of a peculiar characteristic of the solid state receivers in the aircraft. These receivers saturate at approximately 280 μa but only when the signal is modulated predominantly by 90 Hz.

This particular receiver characteristic was not considered detrimental for the purposes of the present [illegible] because the achieved clearances for all of the tested [illegible] were well above the required

levels. If one wished to investigate the sources of reflections causing the scalloping on the clearances in more detail, or indeed the maximum level of clearance on the 90 ~ side of the course, one could, as Mr. H. L. [illegible] of [illegible] correctly observed, excite the array with power [illegible].

From initial flight checks of the type 2 localizer at an elevation of [illegible] feet MSL, it was determined that the radiated patterns were essentially symmetrical.

In contrast with the scalloping of the clearances produced by the 8 loop BFI clearance array, the scalloping observed using either the type 0 clearance array or the type CA-1 clearance array was approximately 15 μa on the 90 ~ side of the course and approximately 30 μa maximum on the 150 ~ side of the course. The considerable difference in the levels of the scalloping is due in part to the fact that the signals of the two arrays are contained within approximately [illegible]° sector centered on the front course. The signal radiated by the eight loop clearance array is believed to be more or less omni-directional and, therefore, illuminates more of the available reflecting surfaces.

Dwg. 332-5015 shows a top view of the buildings and terrain surrounding the Boeing Field. Dwg. A332-5015 is a portion of the 7.5 minute Geological Survey map entitled "Seattle South, Washington, Quadrangle, photo revised [illegible]."

The present course quality of the BFI facility according to the FAA specification is CAT I quality, see Table V.

E. Measurement to Determine Effect of Test Arrays Mounted In Front of BFI Localizer

Because the Boeing Field facility serves as an emergency backup for the Seattle-Tacoma International Airport, it was necessary to know to what degree the test arrays mounted in front of the BFI facility would interfere with the quality of the guidance signal provided by the BFI facility. This information was also required for Boeing Field use since the BFI facility was to be placed back in service each day following the tests of the developmental arrays.

It had been previously observed during the type 0 array tests at Harrisburg that essentially no interference with that facility resulted when the type 0 array was mounted approximately 175 feet in front of the FAA waveguide course array. In the Boeing Field tests, however, the type 0 array, at least during the first portion of the test program, was to be located approximately 135 feet in front of the waveguide array. A comparison of the 6 NM clearance orbit data and a comparison of low approach data with and without the test array in front of the waveguide array did not indicate any discernable interference. See data for runs 2, 5, and 15 in Table II and data for runs 3, 4, 11, 13, 14, 15 and 16 from Table V.

As a result of comparison of the measured data obtained with and without the type 2 localizer in front of the BFI localizer, it was the opinion of WE-FTDD-SCEA and of the engineers from the FAA and AACE, that no significant degradation of quality to the BFI facility had occurred. The BFI localizer was, therefore, put back into normal service during all periods when the developmental arrays were not being tested.

F. 6NM Clearance Orbits - Table II

For all test configurations, 6 NM clearance orbits were flown at 1500 ft above MSL for a minimum ±35° sector from the front course. A summary of the results of these clearance orbits are given in Table II. The minimum clearance measured within the ±35° was 200 μa with the type 1A array. This array, however, is designed to start cutting off close to 35° so that an error in angle of 2° or 3° could mean the difference between indicated clearances of 200 μa at 35° in one case to perhaps as high as 330 μa in another case. Previous flight data taken on the type 1A array at NAFEC does show the sharp cut off in the clearances quite clearly. The data from NAFEC shows clearances as high as 325 μa at both +35° and -35° on the same orbit.

It was found during the reduction of the site test data that in some cases the marks indicating ±10° or ±35° were not always symmetrical with the crossover point. It was also observed that on consecutive runs or successive runs of essentially the same test that the clearances at the indicated angles did not always agree. This phenomenon has been observed on a number of previous test flights. It would appear as if a sudden tail wind or an increase in aircraft speed caused the aircraft to traverse one portion of the sector faster than another equal portion of the sector. This effect would make the angle markings on the recordings look unsymmetrical. Another possible cause is slowness of the AVC circuit. In other cases, small errors have occurred in the marking on the recording of the angles from the course because ground points were used. In reducing the data, some

subjectivity is involved in determining the angle.

Data for portions of some 6.0 NM orbits are shown on Dwgs. A332-50[illegible], -5017, -5018, -5019, and -5020. These drawings show a portion of the actual recordings respectively for runs No. 2, 15, 3[illegible], 4[illegible], and [illegible]8. Runs 2 and 15 show the RFI waveguide localizer clearance with and without the type 2 localizer mounted in front. Run 3[illegible] shows the clearances for the type 2 localizer "in wide alarm." Runs 47 and 48 show the clearance for the type 1B localizer 1) with a 200 ft separation between the course array and the clearance array and, 2) for a separation of 75 feet between the course array and the clearance array. It should be recalled that in both cases, the six element clearance array for the type 1B localizer is firing thru 22 elements and not thru 14 elements as would be the case in a standard 1B installation. No difference in performance, however, is expected.

G. Usable Distance - Table III and Table IV

Usable distance data was recorded for all test configurations of the developmental localizers. The data was taken at an elevation of 1500 feet above MSL at 10 NM and at 18 NM or farther. The 10 NM data was recorded to determine performance at ±10° off the front course.

A definition of the "usable distance" is given in the "United States Standard Flight Inspection Manual" OA P 8200.1 CH617 of August [illegible], 1970. It is cited here in substance for reference: within the usable distance the input RF signal strength at the receiver shall be at least 5 microvolts and will result in a flag alarm current of at least 240 microamperes.

The usable distance data measured at Boeing Field is presented in Table III and Table IV. Data for both receivers is given. The flag currents are given in Table I. Minimum flag currents are given in Table I. The minimum flag current in all tests was 310 micro-amperes. The data presented in Tables III and IV shows that usable distance was achieved at Boeing Field for all test configurations. It is also clear from the data, that at least at Boeing Field, because of the hills located on both sides of the runway, that input powers of 2.8 to 3.0 watts at the 8 element or 6 element clearance arrays results in acceptable signal strength levels at the test altitude of 1500 ft. above MSL.

The AGC voltages given in Table III show that the radiation patterns are reasonably symmetrical. The lack of symmetry indicated by the data given in Table IV is due to the shadow of hills in the direction of 10° on the 90 ~ side of the course. These hills located approximately 3 NM from the localizer are approximately 275 ft. high AMSL. At 18 NM, the aircraft would be below the line sight at 1500 ft. AMSL. The reduction of signal in the direction of 10°/90 ~ at 18 NM compared to the signal in the direction of 10°/150 ~ (also at 18 NM) is approximately 6 to 10 dB. The elevation of the terrain along the 10°/150 radial is relatively low. A portion of this hilly area is shown on Dwg. A332-5015A.

It will be observed from the data given in Tables III and IV that when the AGC voltage levels exceed those corresponding to approximately 100 microvolts or so, the agreement between the two receivers is not good. For AGC levels between about 5 microvolts and 100 microvolts, the agreement is fair. The calibration curves for the aircraft receivers used during the site test are shown on Dwg. A332-5021. Receiver No. 1 for runs 1 thru 36 was Serial No. 1061. Receiver No. 1 for runs 37

thru 76 was Serial No. 1151. Receiver No. 2 for runs 1 thru 76 was Serial No. 1105. As shown on Dwg. A3[illegible] the calibration curve is given in terms of microvolts versus milliamperes. The actual recording from which one reads the milliamperes is calibrated so that one space equals four milliamperes. Since one space on the recording is only 0.1 inch wide, it is difficult to determine the high signal level with great accuracy.

H. [illegible] Alignment and Structure - Table V

Low approaches were made for all test configurations. A summary of the data is given in Table V, sheet 1 and 2. The data given in Table V is the maximum variation of the course, in microamperes, for four different sections of the approach path. The distances which were chosen for this presentation do include those distances where the maximum course bends occur. At Boeing Field, the locations of buildings and of other reflecting surfaces are such that the course bends occur in three sections of the approach path: a) threshold to -2000 ft. down the runway, b) threshold to approximately 3500 ft. in front of the runway, and c) 6000 ft to approximately 15,000 ft. from threshold. No significant course bends were found from approximately 15,000 ft. on out.

As a reference, the criteria for specific course quality categories required by the FAA is given in Appendix A.

In the evaluation of the measured course bend data, it was found, over the period of the testing, that the alignment of the course on a number of tests would look very good, almost dead center. On other tests, however, using the same test configuration, the recorded data would look like there was some fixed offset of the course of the order of 4.0 to 6.0 μa. The reason for the observed offset on some runs and not on others is not known. Offsets of these magnitude are easily corrected by adjustment of the modulation balance.

Xerox copies of portions of the original recordings of low approaches on the BEI facility are shown on Dwgs. A332-5022, -5023, and -[illegible]. These drawings show relevant parts of low approaches on the BEI facility operating normally, the 8 loop array alone, and the waveguide array alone. See runs No's 4, 6 and 9. It is seen from these recordings, that the course bends look reasonably symmetrical with runway centerline. The alignment of the BEI arrays, based on the measured data, seems to be very good. In order to verify this alignment, however, long sections of the original recordings have to be examined. It should also be noted from these recordings, that the theodolite data becomes very rough as the threshold is approached and cannot be relied upon to describe the localizer performance. For low approaches where the theodolite is "rough", the localizer performance is determined from the "raw data" trace. The "raw data" is indeed the only signal on the recording that comes from the localizer. When the theodolite data is good, one can subtract out the relative angular location of the aircraft and end up with a trace that fully describes the course radiated by the localizer. Dwgs. A332-5020 and -5021 show what might be termed very good theodolite data.

Although a large number of "course structure" runs were made, only a representative sample of the runs is presented in this report. Dwg. A33[illegible] shows a portion of a structure run with the type 0 array alone, run No. 1[illegible]. Dwg. A332-5026 shows a portion of the structure run for the [illegible] course array, run No. 20. Dwg. A332-5027 shows a portion of the structure run for the type 2 localizer, run No. 34. Dwg. A332-5028 shows a portion of the special structure run with the type 2 localizer. During the special structure run, two station wagons were driven in front of the course array at a distance of approximately 75 ft., run No. 36. From the submitted data, A332-50[illegible], or indeed from the complete recording, there is no indication that the station wagons were passing in front of the array during the structure run.

Dwg. A332-50[illegible] shows a portion of the structure run for the type 2A self-clearing array, run No. 57. Dwg. A332-50[illegible] shows a portion of the structure run for the type [illegible] clearance array alone, run No. [illegible]. Dwg. A332-5[illegible]1 shows a portion of the structure run for the type 2B localizer system, run No. [illegible].

The measured data for the type 2 localizer does indicate that a Category III course quality was achieved at [illegible]. A comparison between the measured course bend data for the arrays tested and an analysis of the site is given in the next section.

I. Course Bend Analysis - Boeing Field International

In preparation for the site tests at Boeing Field, an initial pre-test site analysis was made to determine what sort of performance might be expected with the type 2 localizer. We wanted to know 1.) can the course quality be improved over the course quality being provided by the standard waveguide facility presently in use, and 2.) if we could improve the course quality, by how much could we improve it and 3.) could we explain to a reasonable degree of certainty why the present facility provides the course quality that it does. In addition, we were also concerned with the level of clearances that we might expect as well as what input powers might be required in order to achieve useable distance at this site. Since clearances greater than 270 microamperes for a 4.4° course width were observed in previous flight tests with the type CB-1 clearance array, we did not anticipate any difficulty with the clearances. Also, since the hills around the site would dictate the required input power, the primary concern centered on the course quality that would be achieved.

In analyzing the site, we believed that the reflections on course would come from essentially three structures. These three structures, labeled A, B, and C are shown (in top view) on Dwg. A332-[illegible]. Other structures located on the Field, or close to it, were considered to be either too small or to be turned in such a way that reflected energy from them would not go down on the part of the course where they would result in objectionable bends.

Structure A is the Air West Hangar. The reflecting surface of this hangar is approximately 230 feet wide and approximately 60 to 70 feet high. The reflecting surface consists of ten partially overlapping metal doors. The setback adjacent between door surfaces is approx. 15 inches.

Structure B is one of the Boeing Company buildings. This structure is approximately 300 feet wide and approximately 30 to 40 feet high.

Structure C is the Boeing Flight Center. This structure is approximately 780 to 800 feet long and approximately 110 feet high. The reflecting surface consists of 13 metal doors. Each door is approximately 60 feet wide. The closed door arrangement is such that the exterior surfaces of all the doors lie in the same vertical plane.

From a preliminary evaluation of the effect of each of the three principal reflecting sources, it is believed that because all three of these structures are essentially parallel to the runway but are located at three greatly different distances down the runway, three distinct areas of course bends may be expected. It was found from the calculations that indeed this is approximately what should occur. Building C is located at about 5.6° angle from the runway centerline as seen from the localizer. It is, therefore, expected to have very little effect at distances less than about +6000 feet beyond the threshold. Building B located at an angle of 6.3° as measured at the localizer may be expected to contribute most to the course bends between approximately +1000 feet and +2000 feet from threshold. Building A could be expected to account for the course bends occurring between approximately -2000 feet down the runway to approximately +3500 feet.

In our preliminary estimate, we attempted to account for the course bends produced by the standard waveguide/8 loop localizer facility presently in use. From a structure run of the waveguide

facility flight of October 1972. The maximum course bends were found to be approximately ±10 microamperes. Later measurements have shown that this was approximately correct. In addition, another FIDO structure run showed the effect of the eight element array alone. From the data for the eight element array alone, the course bends were found to be approximately ±110 microamperes. Later measurements have also shown that this was correct as well. The maximum course bends for both runs occurred between 0 feet and +2000 feet from the threshold. The plus sign is used to indicate distances measured from the threshold in the direction away from the localizer.

Building A appeared to be a most likely source of the bends, between 0 and +2000 feet. A calculation of the maximum amplitude of the course bends due to building A assuming it to be 80 ft high, gave 17.2 microamperes for the unit localizer. A second calculation of bends from Building A also based on unit localizer, but assuming a 60 ft. hight, indicated maximum course bends of approximately 8.0 microamperes. What this meant is that in order to account for the observed 110 microamperes obtained with the 8 loop array alone, the normalized sideband difference of the 8 loop array would have to be between 6.4 to 13.7. For the 4° measured course width, the maximum theoretical value of the normalized sideband difference (NSD) for an 8 loop array is only 2.5. Alternatively, if the course width of the 8 loop array was very sharp, then a large NSD would result. It also seemed possible that there is a large source of reflection which was not shown on the drawings at hand. In any event, we could not, at the time, account for the measured course bends observed with the 8 loop array and decided to hold off on a more detailed analysis until the additional information was gathered.

Since the ESL of the type 2 course array for a 4° course width is below .02 for angles greater than approximately 7.0°, we could still estimate the expected level of the course bends. Let us assume a "worst case", namely, that the type CB-1 clearance array would result in bends around ±100 micro-amperes. If we then adjust the input power of the arrays to achieve a capture ratio of [illegible] db, we could expect the course bend to be reduced to approximately ±[illegible] microamperes. This would mean that the expected improvement in course quality would be a factor of 2 or even 3.

From the tests, it was found that we were correct in both the initial estimate and in our suspicions.

1. The course quality was improved by a 3:1 factor, and,
2. The analysis of the course bends showed that the probable source of the 110 microampere reflection [illegible] hill, and not any of the buildings [illegible]

It was believed that if we analyzed all the structures [illegible] different arrays that by knowing the ESL's, a simple relationship [illegible] be shown to exist between the ESL's in the direction of the reflection source and the measured course bends. This was found to be the case.

Because the measured course bends observed with the 8 loop array were indeed ±110 microamperes for approximately a 4.0° measured course width, it was believed that the sideband pattern may not be the same as the published theoretical pattern. The RF patterns of the 8 loop array were measured at an altitude of 3,[illegible]00 feet. The measured patterns are plotted on Dwg. A572-5132. The measured patterns were plotted assuming that the losses in the distribution circuit were the same for [illegible] and the [illegible] signals. We believe that this is a

correct assumption. From the measured pattern data, we were somewhat surprised to find that the maximum NSD in the direction of 10° from the front course appears to be about 4.4. The accuracy of the SO patterns, however, is somewhat in doubt. To partially check the measured pattern data, a comparison was made between the measured DDM observed on normal "clearance orbit" at 6 NM and 3000 ft. elevation on one hand, and the calculated DDM from the measured patterns on the other hand. Dwg. A332-5033 shows this comparison. It can be seen that the agreement between the calculated and measured DDM data is good. This agreement leads us to believe that the course width value of about 4.6° is probably correct. Since a course width of 4.6° would be inconsistent with NSD of 4.4 at 10°, it may be assumed that NSD value of 4.4 is doubtful.

In order to determine the relative level of course bends to be expected from each of the principal reflecting sources, we have constructed a table of NSD's for each array with an NSD value listed, based on the measured course widths, in each of the directions of the reflecting sources, "A", "B", and "C". These directions as measured from the localizer are approximately 5.6°, 6.3° and 8.0°. In addition, for use later in this analysis, the maximum NSD's at or around 20°, 30°, and 40° are also listed, see Table VI.

If the maximum amplitudes of the measured course bends over a section of the course are proportional to the values of the NSD's from a number of different arrays in a direction of a suspected reflecting objects, there would be strong evidence that the suspected object is the reflecting object. A plot of the NSD's of the arrays versus maximum amplitudes of the course bends should be a straight line.

Since there are several distinct groups of course bends at different distances from the threshold along the course, each group probably being produced by different reflecting objects, one has to make several plots taking NSD in the directions of the several suspected reflecting objects. Such plots are shown in Dwgs. A332-5038, -5039, and -5040. The data on Dwg. A332-5038 shows the measured maximum course bend at the distance between +6000 feet to +15,000 feet from the threshold versus the NSD's in the direction of 5.6°. The course bends at these distances seem to be fully accounted for by reflection from Building C alone located approximately at 5.6° as seen from the localizer. The agreement between the expected result based on the proportionality of NSD's and course bend amplitudes as measured is good except for some slight deviation in the case of the C6-1 and the 8 loop arrays. Dwg. A332-5039 shows the same type of comparison for the course bends at distances between -2000 ft. and 0 ft. from the threshold. For this range of distances, the course bends seem to be due almost completely to Building A. Building A is located at an angle of 8.0° from the localizer. The agreement between the theory and the measured data, except for the 8 loop array, is very good. Dwg. A332-5040 again shows the same type of comparison, as shown on Dwgs. A332-5038 and -5039, but for the measured maximum course bend at distances between 0 feet and +3500 ft. from the threshold. While the course bends occurring at distances between 0 feet and +3500 feet from the threshold do come from both reflecting sources A and B, the greatest course bends occur close to the threshold. They would appear to be produced more by reflecting source A than by reflecting

source B. The NSD's shown on Dwg. A332-5040 are those in a direction of 8.0° from the localizer. The NSD values plotted on Dwgs. A332-5038, -5039, and -5040 were taken from "A Guide for the Selection of Antenna Characteristics for Single Frequency and Two Frequency Localizers in the Presence of Reflecting Structures," and adjusted for the measured course width.

It is noted in connection with Dwg. A332-5040 that again a reasonably good linear relationship exists between NSD and course bends for all of the arrays except for the type C6-1 and the 8 loop array; the agreement, however, obtained with the 8 loop array is particularly poor.

It is suggested by the data shown on Dwg. A332-5040 that an additional reflecting source, other than objects A, B and C must be present. Since there is also some disagreement for the Type C6-1 array, as well as the 8-loop array, and further, since the sideband pattern of the C6-1 array is relatively wide, one should look out beyond, say 20°, for the additional reflection source.

From the course bend recording for the 8 loop array, Dwg. A332-5023, we can determine the approximate direction of the reflecting source by measuring the distances between successive maxima of the course bends.

The approximate direction of reflecting source is given by the relationship $\lambda_L / \lambda_f = \frac{1}{1 - \cos \theta}$ where:

λ_L is the distance between successive maxima of the course bends in feet.

λ_F is wavelength at the test frequency.

θ is the angle measured backwards from a point on course where the course bends are being observed. We take the estimated center of the group of the course bends in question.

Performing the indicated mathematical operations using an average spacing between the course bend maxima (approximately 600 feet) centered around a point approximately +800 feet from threshold, we find that the additional reflecting source should be in a direction of approximately 10° from the runway centerline as measured from the point located at +800 feet from the threshold. The direction of the source is shown by the "direction arrow" on Dwg. A332-5015. Even when the direction of the source is known, there is still a problem to determine what this additional source really is.

If we look back from +800 ft. at an angle of 10° on the 150 cycle side, no significant reflecting source is found. If we look back from +800 ft. at 10° on the 90 cycle side, the direction arrow goes right through reflecting source A. We cannot, however, conclude that we are completely in error with regard to source A for one array and, at the same time, be correct with regard to source A for five or six other arrays. We conclude that there must be an additional reflecting source beyond source A and that this source is closer to the localizer.

If we look for the probable sources of reflection in the indicated direction, we find two candidate sources:

1. An extensive array of telegraph wires located approximately 30 feet above ground and running parallel to the railroad tracks shown on Dwg. A332-5015.
2. A relatively broad sloping hillside rising 70 to 80 feet above the runway and extending for a distance of approximately 3000 ft. The hillside of interest is located at angles between 20° and 40° from the localizer. A portion of this area has been enclosed by a dashed line and designated as source D, see Dwg. A332-5005.

It may be assumed that the reflection from the telegraph wires 30 feet high would be less than from a flat metal wall 30 feet high. Assuming such a wall 6000 feet long, we find that the reflection from this wall when it is illuminated by an 8-loop array would produce bends around 2.0 microamperes, and not 110 microamperes. The telegraph wires, must, therefore, be dismissed as a possible candidate. This leaves only the hillside and a substantial row of trees on the hillside as the only possible sources.

J. Vertical Polarization Measurements

Vertical polarization was measured on the Type 0 array, Type 2 System, and the Type 1B System. The measurements were made on the inbound portion of course structure runs No's 18, 33, 34, 40, 48, 61, and 68.

The effect of the vertical polarization as shown on the recordings for the runs given above appear as a slow change in course direction. No sudden displacement of cross pointer indication was observed on any of the vertical polarization checks.

The maximum value of course shift that was observed for a standard ±20° wing dip was ±4.0μa. This variation was observed during the inbound portion of structure run No. 34 on the type 2 localizer system. The portion of this run showing the vertical polarization check is given on Dwg. A332-5041. Other measurements of the vertical polarization for the same type 2 localizer, runs No. 33 and 68, however, showed a negligible vertical polarization effect.

The maximum vertical polarization effect that was measured with the type 1B localizer system was ±2 μa. The vertical polarization effect with the 1B course array alone, run No. 40, was less than ±1μa. Since these arrays are all constructed from the same type of element, one would not expect to find any significant differences in the vertical polarization effect for different arrays.

The FAA Specification on vertical polarization effect is given below: United States Standard Flight Inspection Manual, [illegible], 8/[illegible]/7[illegible], [illegible] (5) [illegible]. The maximum displacement [illegible] the course line due to vertical polarization effects shall not exceed [illegible]μa for Category I or ±8μa for Category II facilities.

COURSE BEND CRITERIA

CATEGORY I.

Maximum variation of course indications from runway centerline starting from the ILS reference datum* (100 ft. above threshold) to 3500 ft. from threshold is ±15 μa. From 3500 ft. to 4 NM, the maximum variation is allowed to increase linearly from ±15 to ±30 μa.

CATEGORY II

Maximum variation of course indicator from runway centerline starting from the ILS reference datum to 3500 ft. from the threshold is ±5 μa. From 3500 ft. to 4 NM, the maximum variation is allowed to increase linearly from ±5 to ±30 μa.

CATEGORY III.

Category III encompasses Category II and in addition provides that the maximum variation of course indicator from the ILS reference datum (100') to a point 20 ft. above the runway and 2000 ft. down the runway shall also remain within ±5 μa.

*The distance, measured on the ground, between the threshold and a point lying directly under the ILS reference datum will depend on the location of the glide slope and the glide slope angle.

TABLE I

SHEET 1 of 5

SITE TEST - BOEING FIELD INTERNATIONAL

LIST OF FLIGHT TESTS, 8/23/72 - 9/1/72

FAA AIRCRAFT N16 - DC-3 TYPE

RUN #	DATE	TEST CONFIGURATION LOCALIZER		TEST DESCRIPTION	INPUT POWER WATTS CS	 SO	COURSE WIDTH DEG.	FLAG CURRENT MICRO-AMPS. MINIMUM
1	8/23	BFI FACILITY (NORMAL)	WAVEGUIDE 8 LOOP	COURSE WIDTH ADJUST.	91.0 43.0	3.52 .77	4.0 4.0	
2	8/23	BFI FACILITY	WAVEGUIDE 8 LOOP	6 N.M. 1,500 ft. MSL ± 45° ORBIT	91.0 43.0	3.52 .77	4.0 4.0	300.
3/4	8/23	BFI FACILITY	WAVEGUIDE 8 LOOP	RTT LOW APPROACH 18 N.M.	91.0 43.0	3.52 .77		
5	8/23	BFI FACILITY	-------- 8 LOOP	6 N.M. 1,500 ft. MSL ± 45° ORBIT	---- 43.0	--- .77	--- 4.0	
6/7	8/24	BFI FACILITY	-------- 8 LOOP	RTT LOW APPROACH 10 N.M.	---- 43.0	--- .77	--- 4.0	
8/9	8/24	BFI FACILITY	WAVEGUIDE --------	RTT LOW APPROACH 10 N.M.	91.0 ----	3.52 ---	4.0 ---	
10	8/24	BFI FACILITY	WAVEGUIDE --------	6 N.M. 1,500 ft. MSL ± 35° ORBIT	91.0 ----	3.52 ---	4.0 ---	
11	8/24	BFI FACILITY	WAVEGUIDE 8 LOOP	RTT LOW APPROACH 18 N.M.	91.0 43.0	3.52 .77	4.0 4.0	
12(1)	8/24	BFI FACILITY	WAVEGUIDE 8 LOOP	6 N.M. 1,500 ft. MSL ± 35° ORBIT	91.0 43.0	3.52 .77	4.0 4.0	
13	8/24	BFI FACILITY	WAVEGUIDE 8 LOOP	RTT LOW APPROACH 18 N.M.	91.0 43.0	3.52 .77	4.0 4.0	
14	8/24	BFI FACILITY	WAVEGUIDE 8 LOOP	RTT LOW APPROACH 18 N.M. USEABLE DISTANCE 10 N.M. 2,000 ft.	91.0 43.0	3.52 .77	4.0 4.0	
15(2)	8/25	BFI FACILITY	WAVEGUIDE 8 LOOP	6 N.M. 1,500 ft. M.S.L., ± 35° ORBIT USEABLE DISTANCE 18 N.M.. RTT LOW APPROACH 18 N.M. COURSE WIDTH 8 LOOP	91.0 43.0	3.52 .77	4.0 4.0	
16	8/25	BFI FACILITY	WAVEGUIDE 8 LOOP	RTT LOW APPROACH 10 N.M.	91.0 43.0	3.52 .77	4.0 4.0	

(1) 8 ELEMENT ARRAY ERECTED 136 ft. in front of WAVE GUIDE ARRAY

(2) IN ADDITION TO 8 ELEMENT ARRAY THE 22 ELEMENT ARRAY IS NOW ERECTED 335 ft. IN FRONT OF WAVE GUIDE ARRAY

TABLE I

SHEET 2 of 5

SITE TEST - BOEING FIELD INTERNATIONAL

LIST OF FLIGHT TESTS, 8/23/72 - 9/1/72

FAA AIRCRAFT N16 - DC-3 TYPE

RUN #	DATE	TEST CONFIGURATION: LOCALIZER	TEST DESCRIPTION	INPUT POWER WATTS: CS	INPUT POWER WATTS: SO	COURSE WIDTH DEG.	FLAG CURRENT MICRO-AMPS.: MINIMUM
17(1)	8/29	TYPE 2 8 EL ARRAY	COURSE WIDTH ADJ. 6 N.M. 1500 ft., MSL ± 45° ORBIT 6 N.M. 2500 ft., MSL ± 45° ORBIT	3.1	.080	4.2	360. 355.
18	8/29	TYPE 2 8 EL ARRAY	USEABLE DISTANCE 0° 24 N.M. 0° 18 N.M., 2-RTT LOW APPROACHES	3.1	.080	4.2	
19	8/29	TYPE 2 22 EL ARRAY	COURSE WIDTH ADJ. 6 N.M. 1,500 ft. M.S.L. ± 15° ORBIT	11.0	.048	4.1	360
[illegible]/22	8/29	TYPE 2 22 EL ARRAY	USEABLE DISTANCE 0° 23 N.M. 1,500 ft. 3-RTT LOW APPROACHES	11.0	.048	4.0	
23/24	8/29	TYPE 2 8 EL ARRAY 22 EL ARRAY	COURSE WIDTH CHECK 6 N.M. 1,500 ft. M.S.L. ± 40° ORBIT	3.0 10.8	.075 .046	4.2 4.1	340
25	8/29	TYPE 2 AS ABOVE	6 N.M. 2,500 ft. M.S.L. ± 40° ORBIT				
26	8/29	TYPE 2 22 EL ARRAY 8 EL ARRAY	USEABLE DISTANCE 18 N.M. 1,500 ft. ± 15° RTT LOW APPROACH 18 N.M.	10.8 3.0	.046 .075	4.1 4.[illegible]	360
27	8/29	TYPE 2 22 EL ARRAY 8 EL ARRAY	USEABLE DISTANCE 10 N.M.	10.8 3.0	.046 .075	4.1 4.2	
28	8/29	TYPE 2 22 EL ARRAY 8 EL ARRAY	RTT LOW APPROACH 18 N.M.				
29	8/30	TYPE 2 8 EL ARRAY	COURSE WIDTH CHECK	2.9	.075	4.3	
30	8/30	TYPE 2 22 EL ARRAY	COURSE WIDTH CHECK & ADJ.	10.8	.048	4.1	
31	8/30	TYPE 2 22 EL ARRAY 8 EL ARRAY	POWER ADJ. 6 N.M. 1,500 ft. M.S.L. ± 40° ORBIT	6.0 2.95	.026 .075	4.1 4.3	350
32, 33/34	[illegible]	TYPE 2 22 EL ARRAY 8 EL ARRAY	USEABLE DISTANCE 20 N.M. 3 RTT LOW APPROACHES 18 N.M., 10 N.M.	6.0 2.95	.026 .075	4.1 4.3	
[illegible]	[illegible]	TYPE 2 22 EL ARRAY	ADJ. 22 EL ARRAY FOR VERY WIDE ALARM CONDITION	6.0	.010	6.2	

(1) THE 8 ELEMENT CLEARANCE ARRAY USED WITH THE 22 ELEMENT COURSE ARRAY IS THE SAME 8 [illegible] SIDE-CLEARANCE ARRAY WHICH IS CALLED A TYPE "[illegible]" ARRAY BY THE F.A.A.

TABLE I

SHEET 3 of 5

SITE TEST - BOEING FIELD INTERNATIONAL

LIST OF FLIGHT TESTS, 8/23/72 - 9/1/72

FAA AIRCRAFT N16 - DC-3 TYPE

RUN #	DATE	TEST CONFIGURATION		TEST DESCRIPTION	INPUT POWER WATTS		COURSE WIDTH DEG.	FLAG CURRENT MICRO-AMPS.
		LOCALIZER			CS	SO		MINIMUM
[illegible]	[illegible]	TYPE 2	22 EL ARRAY 8 EL ARRAY	6 N.M. 1,500 ft. M.S.L., ± 40° ORBIT	6.0 2.8	.010 .075	6.2 4.3	340.
[illegible]	[illegible]	TYPE 2	22 EL ARRAY 8 EL ARRAY	PTT LOW APPROACH	5.95 2.9	.010 .075	6.3 4.3	
38	[illegible]	TYPE 2	22 EL ARRAY 8 EL ARRAY	SPECIAL PTT LOW APPROACH WITH TWO (2) MOVING STATION WAGONS DRIVING IN FRONT OF 22 EL. ARRAY	5.95 2.8	.010 .075	6.3 4.3	
[illegible]	8/3[illegible]	TYPE 1B	14 EL ARRAY --------	COURSE WIDTH ADJ. - 6 N.M. 1,500 ft. M.S.L. ± 20° ORBIT	8.9 ----	.093 ---	4.2 ---	360.
[illegible]	[illegible]	TYPE 1B	14 EL ARRAY --------	USEABLE DISTANCE 20 N.M. 1,500 ft. M.S.L. ± 15° PTT LOW APPROACH 18 N.M., 10 N.M.	9.0 ----	.093 ---	4.2 ---	350.
[illegible]	[illegible]	TYPE 1B	-------- 6 EL ARRAY	COURSE WIDTH ADJ.	---- 2.8	--- .135	--- 7.0	
43	8/3[illegible]	TYPE 1B	14 EL ARRAY 6 EL ARRAY	6 N.M. 1,500 ft. M.S.L. ± 40° ORBIT USEABLE DISTANCE 20 N.M., 1500 ft. ± 15°	9.0 2.8	.093 .135	4.2 7.0	360.
[illegible]	[illegible]	TYPE 1B	14 EL ARRAY 6 EL ARRAY	2 PTT LOW APPROACHES	9.0 2.8	.093 .135	4.2 7.0	
[illegible]	8/31	TYPE 1B	14 EL ARRAY 6 EL ARRAY	USEABLE DISTANCE 10 N.M., 1,500 ft. M.S.L. ± 45° ORBIT	8.8 3.0	.093 .135	4.2 7.1	355.
[illegible]	8/31	TYPE 1B	14 EL ARRAY 6 EL ARRAY	6 N.M. 1,500 ft. M.S.L. ± 40° ORBIT	4.4 3.0	.047 .135	4.2 7.1	
[illegible]	8/31	TYPE 1B	14 EL ARRAY	USEABLE DISTANCE 18 N.M., 1,500 ft. M.S.L. ± 15° PTT Low Approach 18 N.M.	4.5 3.0	.048 .135	4.2 7.1	
[illegible]	8/31	TYPE 1B	-------- 6 EL ARRAY	6 N.M. 1,500 ft. M.S.L. ± 45° ORBIT	---- 3.0	--- .135	--- 7.1	360.
[illegible]	8/31	TYPE 1A (14 Elements)		COURSE WIDTH ADJ. 6 N.M., 1,500 ft. M.S.L. ± 40° ORBIT - USEABLE DISTANCE 18 N.M., 1,500 ft. ± 15°	4.5	.080	4.3	360.

TABLE I

SHEET 4 of 5

SITE TEST - BOEING FIELD INTERNATIONAL

LIST OF FLIGHT TESTS, 8/23/72 - 9/1/72

FAA AIRCRAFT N16 - DC-3 TYPE

RUN #	DATE	TEST CONFIGURATION LOCALIZER	TEST DESCRIPTION	INPUT POWER WATTS CS	INPUT POWER WATTS SO	COURSE WIDTH DEG.	FLAG CURRENT MICRO-AMPS. MINIMUM
[illegible]1(4)	8/31	TYPE 1A	RTT LOW APPROACH 15 N.M.	4.5	.080	4.3	310
[illegible]	8/31	TYPE 1A	USEABLE DISTANCE 10 N.M. 1,500 FT. M.S.L. ±40° ORBIT	4.5	.080	4.3	310
[illegible]3	8/31	TYPE 1A	RTT LOW APPROACH	4.5	.080	4.3	
[illegible]4	8/31	TYPE 1B ---------- 6 EL ARRAY	COURSE WIDTH CHECK 6 N.M. 1,500 FT. M.S.L. ±40° ORBIT	--- 3.0	---- .130	--- 7.15	360
[illegible]5	8/31	TYPE 1B ---------- 6 EL ARRAY	RTT LOW APPROACH 10 N.M.	--- 3.0	---- .130	--- 7.15	
[illegible]	8/31	TYPE 1B 14 EL ARRAY ----------	COURSE WIDTH ADJUST.	4.5 ---	.060 ----	3.8 ---	
[illegible]7	8/31	TYPE 1B 14 EL ARRAY 6 EL ARRAY	COURSE WIDTH CHECK BOTH ARRAYS	4.5 3.0	.060 .130	4.35 --	
58	8/31	TYPE 1B 14 EL ARRAY 6 EL ARRAY	6 N.M. 1,500 FT. M.S.L. ±40° ORBIT	4.5 2.9	.060 .120	3.8 ---	360
[illegible]	8/31	TYPE 1B 14 EL ARRAY 6 EL ARRAY	USEABLE DISTANCE 10 N.M. 1,500 FT. M.S.L. ±40°	4.5 2.9	.060 .120	3.8 ---	340
[illegible]	8/31	TYPE 1B 14 EL ARRAY 6 EL ARRAY	USEABLE DISTANCE 18 N.M. 1,500 FT. M.S.L. ±15°	4.5 2.9	.060 .120	3.8 ---	
[illegible]	8/31	TYPE 1B 14 EL ARRAY 6 EL ARRAY	RTT LOW APPROACHES 18 N.M., 10 N.M.	4.5 2.9	.060 .120	3.8 ---	
[illegible]3	8/31	TYPE 2 22 EL ARRAY 8 EL ARRAY	COURSE WIDTH CHECK	11.0 3.0	.048 .078	4.3	360
[illegible]4	8/31	TYPE 2 22 EL ARRAY 8 EL ARRAY	6 N.M. 1,500 FT. ±40° ORBIT	11. 3.	.048 .07		360
[illegible]5	8/31	TYPE 2 22 EL ARRAY 8 EL ARRAY	USEABLE DISTANCE, 1500 FT. M.S.L. ±45° ORBIT	11. 3.	.048 .078		340
66	8/31	TYPE 2 22 EL ARRAY 8 EL ARRAY	USEABLE DISTANCE 10 N.M., 1500 FT. M.S.L.	11. 3.	.04 .07		340.
[illegible]7[illegible]	8/31	TYPE 2 22 EL ARRAY 8 EL ARRAY	LOW APPROACH 15 N.M. AIR WEST HANGAR DOOR CLOSED	11. 3.0	.048 .078		340

(4) 8 ELEMENT ARRAY MOVED FROM 200 FEET BEHIND 22 ELEMENT ARRAY TO 75 FEET BEHIND 22 ELEMENT ARRAY.

TABLE I

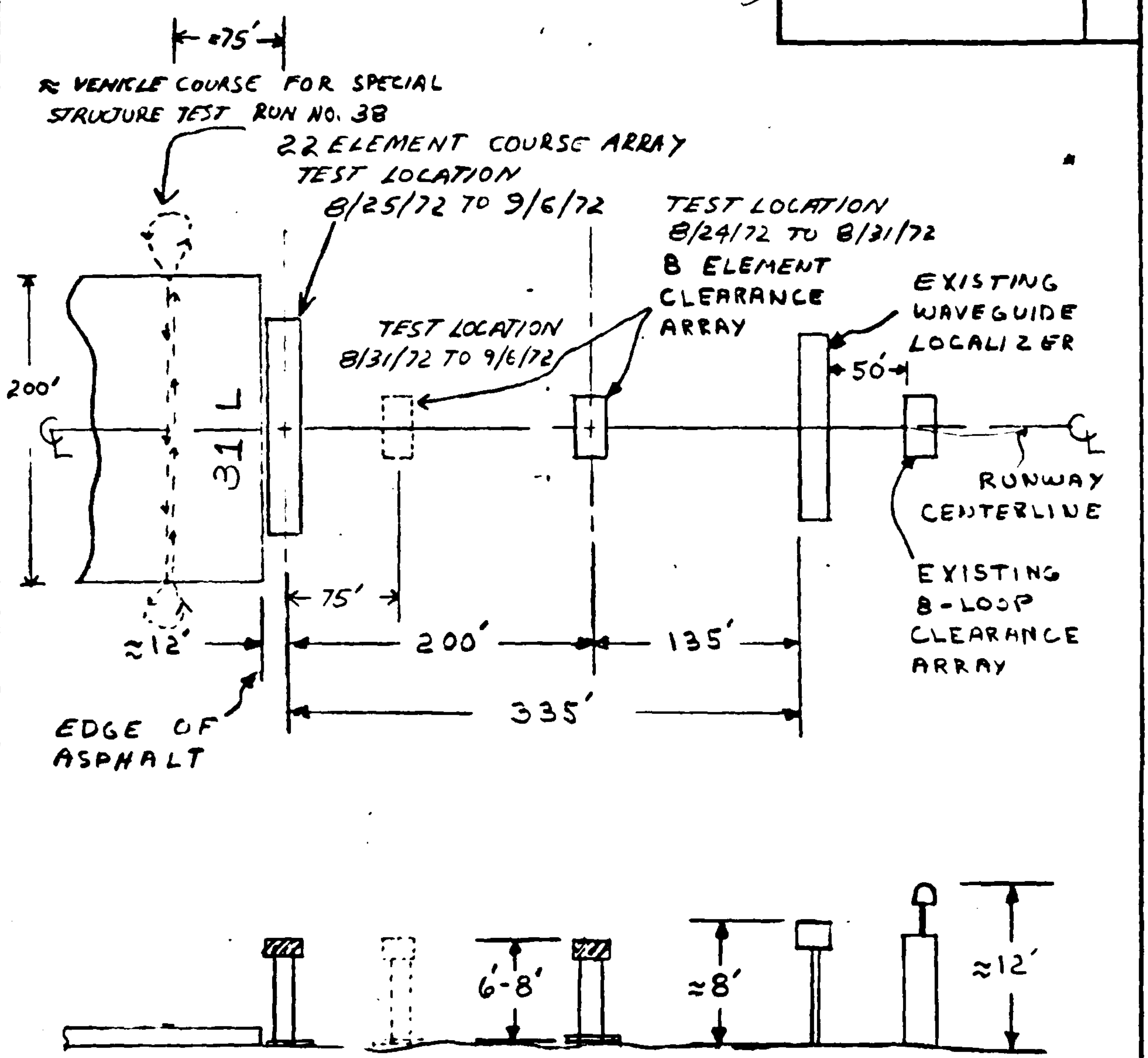
SHEET 5 of 5

SITE TEST - BOEING FIELD INTERNATIONAL

LIST OF FLIGHT TESTS, 8/23/72 - 9/1/72

FAA AIRCRAFT N16 - DC-3 TYPE

RUN #	DATE	TEST CONFIGURATION	TEST DESCRIPTION	INPUT POWER WATTS		COURSE WIDTH DEG.	FLAG CURRENT MICRO-AMPS.
		LOCALIZER		CS	SO		MINIMUM
69	9/1	TYPE 2 22 EL ARRAY 8 EL ARRAY	LOW APPROACH 15 N.M. AIR WEST HANGAR DOOR CLOSED	11.0 3.0	.048 .078		
70	8/31	TYPE 2 ---------- 8 EL ARRAY	LOW APPROACH 8 NM AIR WEST HANGAR DOOR CLOSED	---- 3.1	---- .078		
71	8/31	TYPE 2 ---------- 8 EL ARRAY	LOW APPROACH 8 N.M. AIR WEST HANGAR DOOR OPEN	---- 3.1	---- .078		
72	8/31	TYPE 2 22 EL ARRAY ----------	LOW APPROACH AIR WEST HANGAR DOORS OPEN	11.0 ----	.048 ----		
73	9/1	BFI FACILITY ---------- 8 LOOP ARRAY	6 N.M. 3000 FT.M.S.L. ±90° ORBIT	---- 43.0	---- 0.77	4.0	
74	9/1	BFI FACILITY ---------- 8 LOOP ARRAY	RF CARRIER PATTERN 6 N.M., 3000 FT. MSL ±90° ORBIT	---- 43.0	---- ----		
75	9/1	BFI FACILITY ---------- 8 LOOP ARRAY	R.F. "SIDEBANDS ONLY" PATTERN, 6 N.M., 3000 FT. M.S.L. ±90°	---- ----	---- 43.0		
76	9/1	BFI FACILITY WAVEGUIDE ARRAY 8 LOOP ARRAY	LOW APPROACH 18 N.M.	91.0 43.0	3.52 0.77	4.0 4.0	
		END OF TESTS					



ISSUE	REVISION	NAME	DATE	SCALE	
B	[illegible]	[illegible]	[illegible]		
				DES	
				DWN 7-24-72	GR
MATERIAL				CHK	
TOLERANCES				APP 10/4/72	R.F.
FINISH					

THIS IS A PART OF THE ABOVE ASSEMBLIES

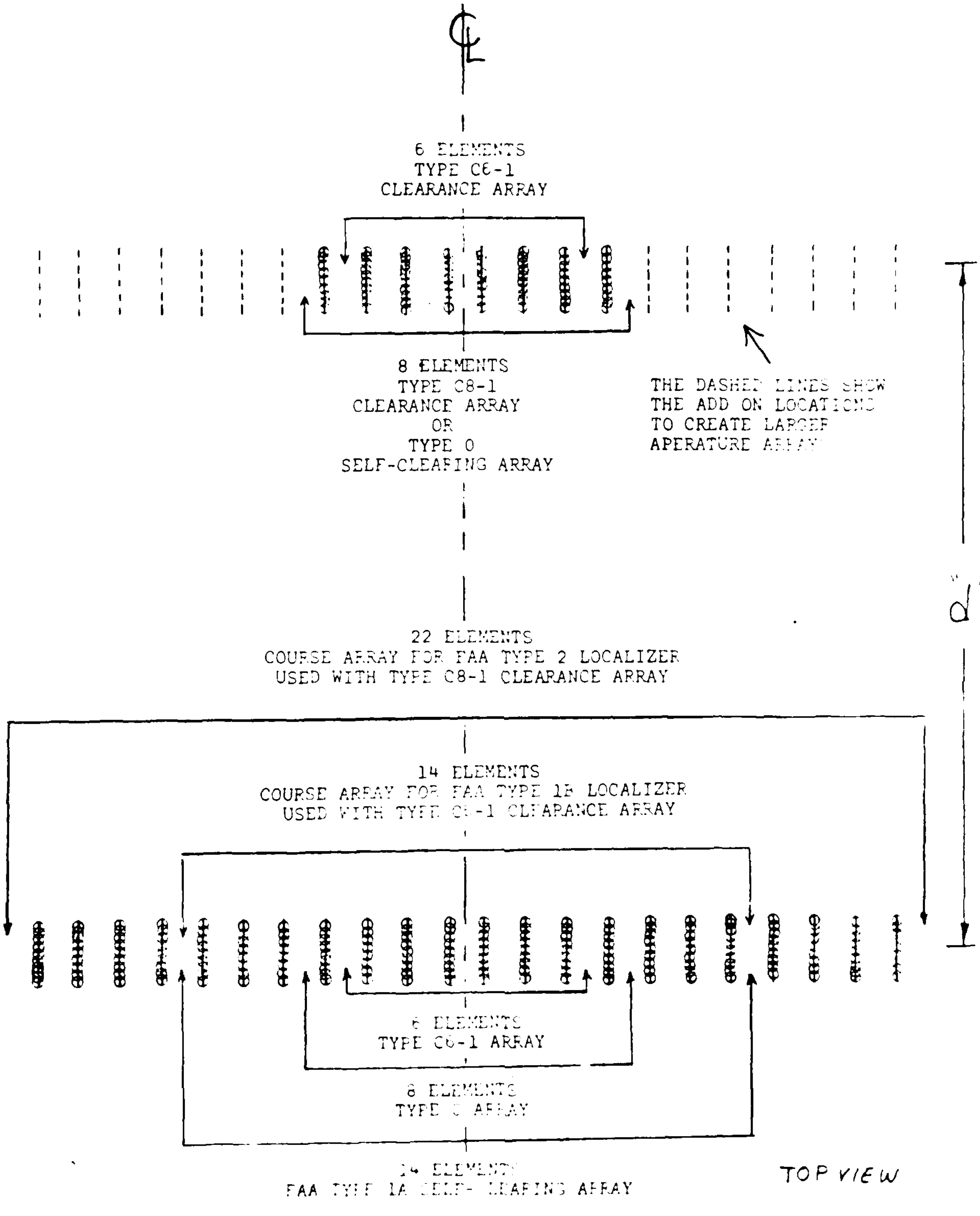
TEMPORARY ARRAY LOCATIONS FOR TYPE II SITE TEST ON RWY 13R - BOEING FIELD INT

A 332 - 5001 B

ANDREW ALFORD CONSULTING ENGINEERS

A-36

AACE FORM NO. 1050-500 18B



PORTION OF TEST CONFIGURATION AND LOCALIZER ARRAY COMBINATIONS FOR THE FAMILY OF LOCALIZER ARRAYS DESIGNED BY AAI UNDER FAA CONTRACT DOTFA[illegible]WA-2253.

AAIE
A332-[illegible]
11-[illegible]

E.F

TABLE II

SITE TEST - BOEING FIELD INTERNATIONAL
6NM-1500 FT MSL CLEARANCE ORBIT

TEST CONFIGURATION	RUN NO.	COURSE WIDTH DEGREES	CLEARANCE LEVEL 150 N SECTOR 35°	30°	20°	10°	6°	5°	1°	0	1°	5°	6°	10°	20°	30°	35° 90 N SECTOR *
LOCALIZER																	
BFI COMMISSIONED FACILITY	2 (1)	4.0	280	290	200	340	310	310		0		280	290	290	210	290	290
BFI 8LOOP ARRAY ALONE	5 (1)	4.0	280		210	240				0				290	220	290	290
BFI COMMISSIONED FACILITY	12 (2)	4.0	280		200	310	300			0		280			220		290
BFI COMMISSIONED FACILITY	15 (3)	4.0	270		200	320	300			0		280			220		285
TYPE O ARRAY (8EL.)	17	4.2	330	345	290	315	300		250	0	270		280		280	270	280
TYPE 2 (22EL. AND 8EL.)	24	4.2	240	300	235	330			280	0				280	235	280	240
TYPE 2 (22EL. AND 8EL.)	31	3.9	260	340	240	330			280	0	280			280	260	280	280
TYPE 2 (22EL. AND 8EL.)	36	6.2	250	330	240	[illegible]			290	0	280			290	240	290	250
TYPE 1B (14EL. AND 6EL)	43	4.2	330	325	335	310			295	0	290			290	290	290	250
TYPE 1B (14EL AND 6EL)	47 (6)	4.2	330	320	340	320			250	0	245			290	290	290	260
TYPE C6-1 ARRAY ALONE (6EL)	49	7.1	330	330	350	290		220		0		220		290	270	290	250
TYPE 1A ARRAY (14EL)	50	4.3	250	355	320	330			290 24°/14°	0	27°/14° 280			290	290	290	200
TYPE C6-1 ARRAY ALONE	54 (4)	7.2	330	320	310	290		220		0		220		290	280	290	260
TYPE 1B (14EL. AND 6EL.)	58	4.35	330	310	340	290			260	0	280			290	280	290	270
TYPE 2 (22EL. AND 8EL.)	64	4.3	260	320	260	320			270	0	285			285	275	285	285
BFI 8LOOP ARRAY ALONE	73 (5)	4.0	310	280	260	330		270	23°/25°	0	25°/28°	275		285	285	285	285

* THE ... LIMIT THE 90 CPS CLEARANCE SIGNAL TO ... N 280 μA TO 2?0 μA

NOTES: (1) NO OBSTRUCTIONS IN FRONT OF BFI FACILITY
(2) TYPE O ARRAY ERECTED 8 ELEMENTS
(3) TYPE 2 COURSE ARRAY ALSO ERECTED, 22 ELEMENTS
(4) MOVED TYPE O ARRAY FORWARD 125 FT.
(5) ALTITUDE 3000 FT MSL.
(6) 10NM NOT 6NM

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DWG. 5542

TABLE II

9/26/72 EF

TABLE III

SITE TEST - BOEING FIELD INTERNATIONAL
USEABLE DISTANCE DATA
10 NM - 1500 FT. MSL ± 35° ORBIT

RUN NO.	TEST CONFIGURATION		CARRIER POWER WATTS	AGC VOLTAGE - MICROVOLTS REC. NO. 1 SER. 1061/1051 ①						AGC VOLTAGE - MICROVOLTS REC. NO. 2 SER. 1105				
	LOCALIZER			35°/150	10°/150	0°	10°/90	35°/90		35°/150	10°/150	0°	10°/90	35°/90
27	TYPE 2	22 EL. ARRAY 8 EL. ARRAY	10.8 3.0	7.6	8.0	300.	46.	6.2		5.4	100.	>1000.	100.	5.4
46	TYPE 3B	14 EL. ARRAY 6 EL. ARRAY	8.8 3.0	14.	72	>1000.	46.	7.4		11.	46.	230.	33	6.8
47	TYPE 1B	14 EL. ARRAY 6 EL. ARRAY	4.5 3.0	9.4	85.	>1000.	60.	8.0		8.2	60.	210.	44.	9.0
52	TYPE 1A		4.5	—	39	>1000.	28.	7.4		—	50.	520.	30	8.2
	MOVED 8 ELEMENT ARRAY		FORWARD	125	FT	SEE	DWG	A						
59	TYPE 1B	14 EL. ARRAY 6 EL. ARRAY	4.5 2.9	7.7	60.	>1000.	60.	8.0		6.8	70.	800.	80.	7.4
65	TYPE 2	22 EL. ARRAY 8 EL. ARRAY	11.0 3.0	5.8	100.	>1000.	100.	5.6		5.4	130.	>1000.	165.	5.0

35°/150 MEANS 35° FROM FRONT COURSE ON THE 150~ SIDE.

NOTES: ① SER. 1061 USED FOR RUNS NO 1 THRU 36
SER 1051 USED FOR RUNS NO. 37 THRU 76

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TABLE III

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TABLE IV

SITE TEST - BOEING FIELD INTERNATIONAL
USEABLE DISTANCE DATA
18 NM OR GREATER, 1500 FT MSL, ± 10° ORBIT

RUN NO.	TEST CONFIGURATION	CARRIER POWER WATTS	DISTANCE N. MILES	AGC VOLTAGE - MICROVOLTS REC. NO 1 SER 1061/1051 ①			AGC VOLTAGE - MICROVOLTS REC. NO 2 SER 1105		
	LOCALIZER			10°/150	0°	10°/90	10°/150	0°	10°/90
15	BFI FACILITY NORMAL	—	18	—	—	—	—	400.	—
18	TYPE O ARRAY	3.0	24	—	—	—	—	40.	—
18	TYPE O ARRAY	3.0	18	—	—	—	—	66.	—
26	TYPE 2 22 EL. ARRAY 8 EL. ARRAY	10.8 3.0	18	12.	71.	5.9	13.	130.	5.0
32	TYPE 2 22 EL. ARRAY 8 EL. ARRAY	6.0 2.8	20	—	71.	6.2	—	62.	6.0
40	TYPE 1B 14 EL. ARRAY	9.0	20	2.4	85	3.5	1.8	100	3.6
43	TYPE 1B 14 EL. ARRAY 8 EL. ARRAY	9.0 2.8	20	10	86	14	9.0	100	11
48	TYPE 1B 14 EL. ARRAY 8 EL. ARRAY	4.5 3.0	18	16	44	6.0	15	46	5.1
50	TYPE 1A	4.5	18	—	38	5.4	—	37	5.2
	MOVED TYPE O ARRAY	FORWARD	125 FT.	SEE DRAWING A					
60	TYPE 1B 14 EL. ARRAY 6 EL. ARRAY	4.5 2.9	18	14.	41.	5.6	15.	50	5.1
66	TYPE 2 22 EL. ARRAY 8 EL. ARRAY	11.0 3.0	18	14.	190.	5.9	15.	280.	5.2

10°/150 MEANS 10° FROM THE FRONT COURSE ON THE 150 ~ SIDE.

NOTE: REC. SER 1061 USED FOR RUNS 1 THRU 36
REC. SER. 1051 USED FOR RUNS 37 THRU 76

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DWG. NO. 5544

TABLE IV

TABLE V

SH 1 OF 2

SITE TEST - BOEING FIELD INTERNATIONAL
COURSE STRUCTURE DATA
SUMMARY

RUN NO.	TEST CONFIGURATION	CARRIER POWER WATTS	COURSE WIDTH DEGREES	MAXIMUM VARIATION OF COURSE STRUCTURE - MICROAMPERES DISTANCES FROM THRESHOLD - FEET 0→-2000'	0→+3500'	6000→15,000	15000'→
	LOCALIZE						
3	BFI FACILITY WAVE GUIDE 8 LOOP		4.0 4.0	±7.	±9.	±5.	±2.
4	BFI FACILITY WAVE GUIDE 8 LOOP		4.0 4.0	±8.	±10	±4	±2
6/7	BFI FACILITY — 8 LOOP		— 4.0	±60.	±110.	±22	±22
8/9	BFI FACILITY WAVE GUIDE —		4.0 —	±3.	±7.	±5.	±2.
11	BFI FACILITY WAVE GUIDE 8 LOOP		4.0 4.0	±8.	±11.	±5.	±2.
13/14 (1)	BFI FACILITY WAVE GUIDE 8 LOOP		4.0 4.0	±9. / ±8.	±13. / ±11.	±5. / ±5.	±2 / ±2.
15/16 (2)	BFI FACILITY WAVE GUIDE 8 LOOP		4.0 3.9	±9. / ±8.	±10. / ±10.	±5. / ±5.	±2. / ±2.
18/18 (3)	TYPE 2 — 8 EL. ARRAY	— 3.0	— 4.2	±33 / ±35.	±32. / ±25.	±14 / ±12	±8. / ±8.
20/21	TYPE 2 22 EL. ARRAY —	11.0 —	4.1 —	±2. / ±2.	±2. / ±3.0	±2.5 / ±3.0	±2.0 / ±2.0
22	TYPE 2 22 EL. ARRAY —	11.0 —	4.1 —	±2.	±3.0	±2.0	±2.0
26/28	TYPE 2 22 EL. ARRAY 8 EL. ARRAY	10.8 3.0	4.1 4.2	±3. / ±2.0	±3.5 / ±3.5	±3.0 / ±3.0	±2.0 / ±2.0
32/33/34	TYPE 2 22 EL. ARRAY 8 EL ARRAY	6.0 2.8	4.1 4.3	+- 4./3./2.5	+- 3.5/5.0/3.0	+- 3.5/3.5/2.5	+- 2./2./2.
37	TYPE 2 22 EL. ARRAY 8 EL. ARRAY	5.95 2.8	6.3 4.3	±2.	±3.	±3.5	±1.5

(1) 8 ELEMENT ARRAY (TYPE O) MOVED ERECTED 135' IN FRONT OF WAVE GUIDE.
(2) 22 ELEMENT ARRAY ERECTED 325' IN FRONT OF WAVE GUIDE.
(3) T... 2 LOCALIZER CONSISTS OF 22 ELEMENT ARRAY AN... ARRAY.

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DWG NO. 5545
SHT 1 of 2

TABLE V
SH. 2 OF 2

SITE TEST - BOEING FIELD INTERNATIONAL
COURSE STRUCTURE DATA
SUMMARY

RUN NO.	TEST CONFIGURATION		CARRIER POWER WATTS	COURSE WIDTH DEGREES	MAXIMUM VARIATION OF COURSE STRUCTURE - MICROAMPERES DISTANCES FROM THRESHOLD - FEET 0→2000'	0→3500'	6000→15000	15000'→
	LOCALIZER							
38 (4)	TYPE 2	2 EL. ARRAY 8 EL. ARRAY	3.95 2.8	6.3 4.3	±2.0	±3.0	±3.5	±1.5
40/41	TYPE 1B	14 EL. ARRAY —	9.0 —	4.2 —	±7.5 / ±8.	±8.5 / ±2.5	±8.5 / ±7.	±20 / ±3.0
44/44	TYPE 1B	14 EL. ARRAY 6 EL. ARRAY	9.0 2.8	4.2 7.0	±[illegible] / ±10	[illegible] / ±8	±8. / ±7.5	±5. / ±4.
45	TYPE 1B	— 6 EL. ARRAY	— 2.8	— 7.0	±22.	±24.	±16.	±10.
48	TYPE 1B	14 EL. ARRAY 6 EL. ARRAY	4.5 3.0	[illegible] 7.1	±11.	±15.	±9.	±3.
49	TYPE 1B	— 5 EL. ARRAY	— 3.0	— 7.1	±40.	±35.	±15	±10.
51/53	TYPE 1A		4.5	4.3	±11 / ±11.	±12 / ±16.	±9. / ±16.	±6 / ±5.
	MOVED [illegible] ELEMENT ARRAY FORWARD BY [illegible] 125' 6 EL. ARRAY IS NOW ≈ 75' IN BACK OF [illegible] ELEMENT ARRAY SEE DWG. A							
55	TYPE 1B	— 6 EL. ARRAY	— 3.0	— 7.15	±30.	±37.	±15	±10.
[illegible]/62	TYPE 1B	14 EL. ARRAY 6 EL. ARRAY	4.5 2.9	3.8 7.15	±11 / ±10.	±12 / ±12	±15 / ±10.	±4. / ±7.
[illegible]/69	TYPE 2	2 EL. ARRAY 8 EL. ARRAY	11.0 3.0	4.3 4.3	±4 / ±13.	±3.5 / ±15	±3. / ±1.	±2. / ±2.
[illegible]/71	TYPE 2	— 2 EL. ARRAY	— 3.1	— 4.3	±30 / ±22	±22 / ±11.	±15 / ±11	±8 / ±8
[illegible]	[illegible]	[illegible]		[illegible]	±[illegible]	±11.	±[illegible]	±2.

[illegible] A332-50[illegible]3 [illegible]

AACE 291
DWG NO. [illegible]

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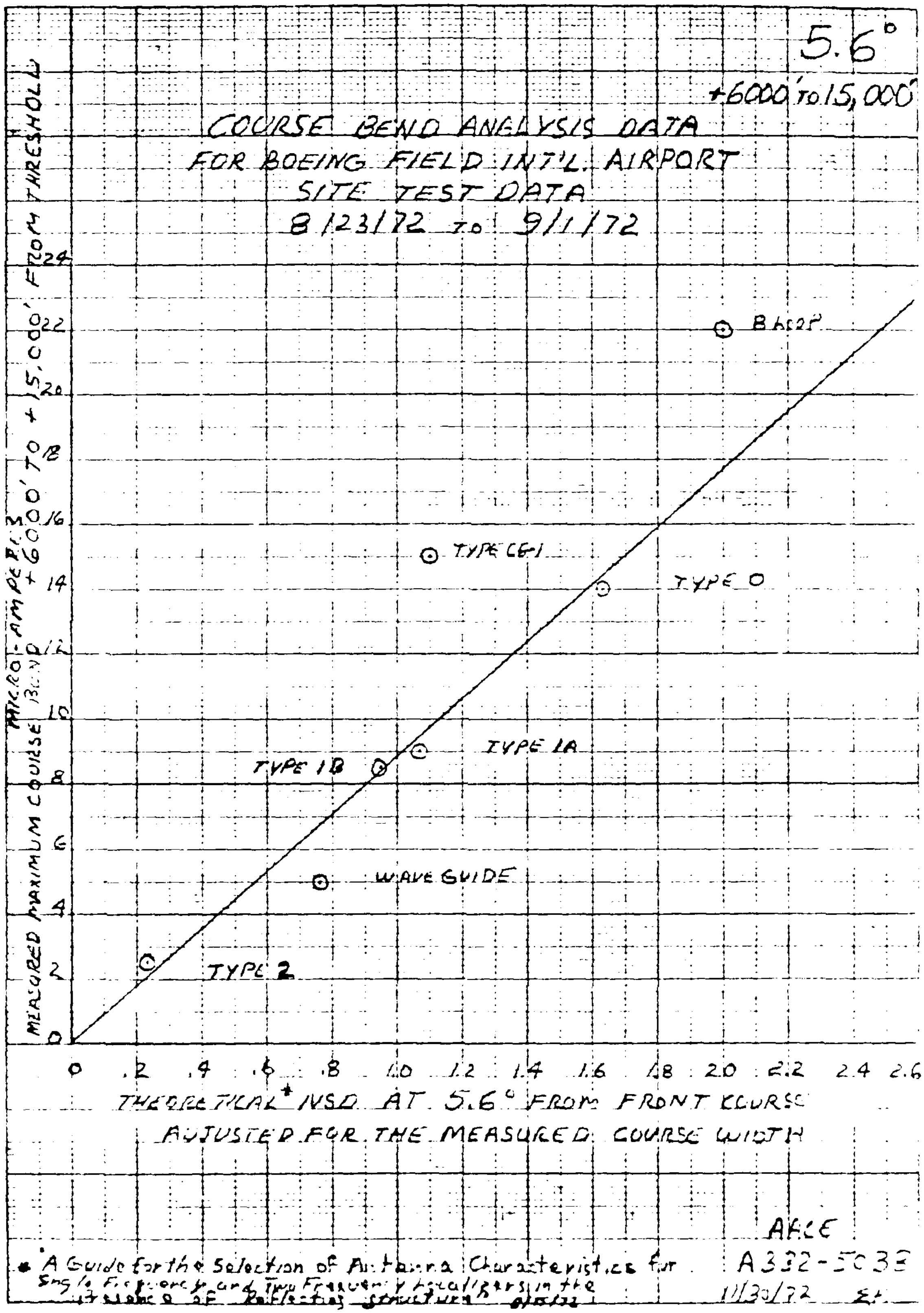
TABLE VI - Comparison of the NSD values for each of the tested arrays in the directions of the principal reflecting sources. Data based on the theoretical distribution of sideband signal and the measured course width at Boeing Field International

NSD (NORMALIZED SIDEBAND DIFFERENCE)

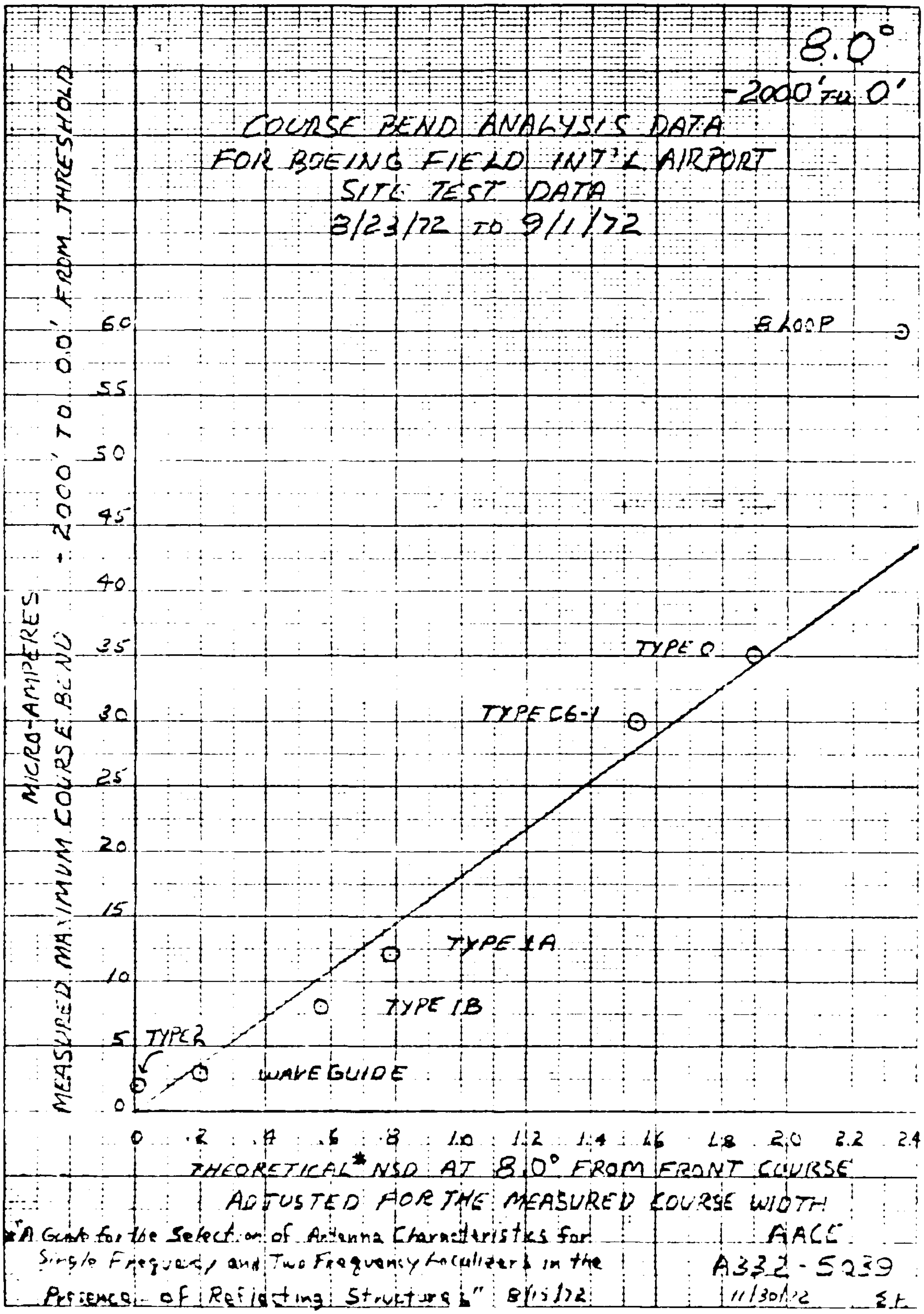
Angle From Front Course TO Reflecting Source		5.6° "C"	6.3° "B"	8.0° "A"	20° "D"	30° "D"	40° "D"
LOCALIZER	Measured Course Width						
Type C6-1	7.0°	1.1	1.18	1.54	1.43	1.06	0.80
8 Loop*	4.0°	2.0	2.1	2.35	1.5	1.05	1.3
8 Loop**	4.7°	2.8**	3.0**	4.0**	1.6	1.24	.22**
Type 0	4.2°	1.63	1.81	1.90	0.46	0.5	0.19
Type 1A	4.3°	1.07	1.02	0.78	0.38	0.35	0.05
Type 1B (Course Array)	4.2°	0.95	0.86	0.57	.035/23°	.036/29°	.021/42°
Waveguide (Course Array)	4.0°	0.76	0.52	0.2	.045/21°	.07/27°	.044/38°
Type 2 (Course Array)	4.1°	0.23	.06	.01	.02/21°	.02/29°	.02/42°

*Theoretical Data

**From flight data, see Dwg. A332-5032, the 0.22 NSD value at 40° is probably due to shielding by the hill. This value has no bearing on the value of the NSD controlling the reflection. The values of NSD at 5.6°, 6.3° and 8° are believed to be in error. These NSD values are taken from the measured SO pattern. The measured SO pattern, however, is questionable because of the difficulty in determining the correct AGC voltage levels when the high end of the receiver curve, greater than 100 μV, rises as steeply as is indicated on Dwg. A332-5021 receiver SER 1051.



5.6°
+6000' TO 15,000'
COURSE BEND ANALYSIS DATA
FOR BOEING FIELD INT'L. AIRPORT
SITE TEST DATA
8/23/72 TO 9/1/72
MEASURED MAXIMUM COURSE BEND MICRO-AMPERES +6000' TO +15,000' FROM THRESHOLD
0
2
4
6
8
10
12
14
16
18
20
22
24
TYPE CE-1
TYPE O
TYPE 1A
TYPE 1B
WAVE GUIDE
TYPE 2
0
.2
.4
.6
.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
THEORETICAL* NSD AT 5.6° FROM FRONT COURSE
ADJUSTED FOR THE MEASURED COURSE WIDTH
AFCE
A332-5C33
11/30/72
* A Guide for the Selection of Antenna Characteristics for Single Frequency and Two Frequency Localizers in the presence of Reflecting Structures



8.0°
-2000' TO 0'
COURSE BEND ANALYSIS DATA
FOR BOEING FIELD INT'L AIRPORT
SITE TEST DATA
8/23/72 TO 9/1/72
MEASURED MAXIMUM COURSE BEND - 2000' TO 0.0' FROM THRESHOLD
MICRO-AMPERES
0
5
10
15
20
25
30
35
40
45
50
55
60
8 LOOP
TYPE 0
TYPE C6-1
TYPE 1A
TYPE 1B
TYPE 2
WAVEGUIDE
0
.2
.4
.6
.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
THEORETICAL* NSD AT 8.0° FROM FRONT COURSE
ADJUSTED FOR THE MEASURED COURSE WIDTH
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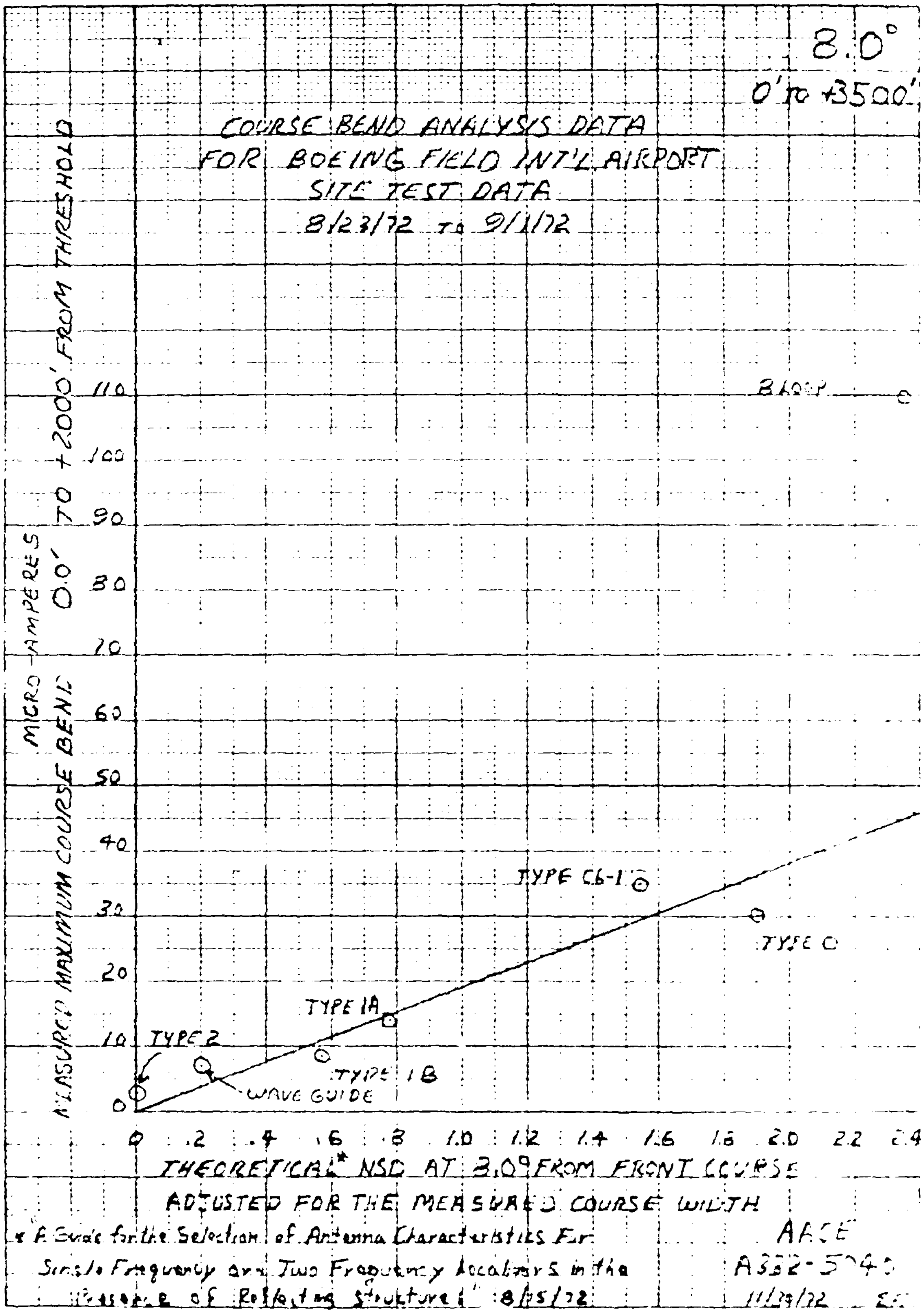
8.0°
0' TO +3500'
COURSE BEND ANALYSIS DATA
FOR BOEING FIELD INT'L AIRPORT
SITE TEST DATA
8/23/72 TO 9/1/72
MEASURED MAXIMUM COURSE BEND MICRO-AMPERES 0.0' TO +2000' FROM THRESHOLD
0
10
20
30
40
50
60
70
80
90
100
110
8 LOOP
TYPE C6-1
TYPE C
TYPE 1A
TYPE 1B
TYPE 2
WAVE GUIDE
0
.2
.4
.6
.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
THEORETICAL* NSD AT 3.0° FROM FRONT COURSE
ADJUSTED FOR THE MEASURED COURSE WIDTH
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DATE
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